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MATHEMATICAL MODEL FOR BARGED OCEAN DISPOSAL OF WASTES

Tetra Tech, Incorporated

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Theoretical and experimental studies were performed on the dispersion and settling of barge disposed wastes in the ocean. A computer program based on the mathematical model has also been written. Comparison of predictions with experiments, both in this study and from previous investigations were found to be good. Example solutions based on the model for prototype situations are also presented.

The waste is assumed to consist of two phases, 1) a solid phase characterized by constituents with various densities and fall velocities, and 2) a liquid phase. The methods of disposal considered include 1) discharge from a bottom opening hopper barge, 2) pumped discharge through a nozzle under a moving barge, and 3) discharge into the barge wake. The effects of ambient horizontal currents, density stratification, variation of diffusion coefficients are incorporated in the model.

Three phases of dispersion are envisioned: 1) a convective phase, 2) a collapse phase, and 3) a long term diffusion phase. Transition between phases is accomplished automatically in the numerical model. In addition, the collapse phase may a) be replaced by, or b) include a bottom spreading phase. Under certain circumstances, the collapse phase is bypassed.

Every attempt has been made to minimize the amount of input required in the use of the numerical model. The integration steps and grid sizes are all automatically chosen by the model. Both detailed printout and graphic output are incorporated. The solution may also be terminated at the end of any of the three phases of dispersion. (EPA)

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(See also W72-01987)

*Mathematical models, *Waste ~~ocean~~ disposal, ~~dredge spoils~~, sewage sludge, liquid wastes, barges, *Waste dilution, *Dispersion, Computer programs, Model studies, *Settling velocity, Great Lakes

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~~dispersion~~
ocean dumping, *Ocean disposal

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MATHEMATICAL MODEL FOR BARGED OCEAN DISPOSAL OF WASTES

by

Robert C. Y. Koh and Y. C. Chang

Grant No. 16070FBY

Program Element 1BA025

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LIST OF SYMBOLS

For simplicity, symbols of secondary importance which appear only briefly in the text are omitted from the following list:

A	dissipation parameter based on variance
A_L	dissipation parameter based on size
B	buoyancy
C_D, C_{D1}, C_{D2}	drag coefficients
C_{drag}	drag coefficient
C_{fictn}	friction coefficient
C_M	apparent mass coefficient
$C_{k,l}$	k, l^th moment of concentration distribution
C_{sij}	concentration of ijth solid
$\vec{D}$	drag force
E	entrainment function
F	buoyancy force
F_f	frictional force
F_1, F_{rictn}	friction coefficients
H	depth
I	inertial force
K	vorticity
K_x	horizontal diffusion coefficient
K_y	vertical diffusion coefficient
K_{y1}, K_{y2}, K_{y3}	vertical diffusion coefficient specified
K_z	horizontal diffusion coefficient
L	length scale
$\vec{M}$	momentum
P_{ij}	volume of ijth solid
R_i	Richardson number
S_{ij}	volume of ijth solid settled out of convective element
$\vec{U}$	velocity vector
$\vec{U}_a$	ambient velocity vector
V	mass
W_1	surface concentration of floating solid
W_2	bottom concentration of settled solid

a	minor axis of collapsing element
b	major axis of collapsing element
c	concentration
g	gravitational acceleration
s	distance along jet or wake axis
t	time
u	velocity component in x-direction
u_a	ambient velocity in x-direction
u_{ao}	ambient velocity in x-direction at surface
v	velocity component in y-direction
v_1	tip velocity due to collapse
v_2	tip velocity due to entrainment
w	velocity component in z-direction
w_a	ambient velocity in z-direction
w_{ao}	maximum ambient velocity in z-direction
w_s	settling velocity of solid particles under consideration
w_{sij}	settling velocity of ijth solid
x	horizontal coordinate
y	vertical coordinate
$y_{k1}, y_{k2}, y_{k3}, y_{k4}$	y-positions where K_y changes values
y_w, y_e, y_u	y-positions where u_a, w_a specified

$\alpha, \alpha_c, \alpha_1$	entrainment coefficients
$\alpha_2, \alpha_3, \alpha_4$	used in convective and collapse phases
α_1, α_2	absorbancy coefficients for solids settling to the bed or free surface
γ_1, γ_2	re-entrainment coefficients for solids settling to the bed or free surface
α_{ij}	settling coefficient
$\theta_1, \theta_2, \theta_3$	angles s makes with x, y, z axes
δ_1, δ_2	angles ambient current makes with x, z axes
Δ_f	$= \rho_a(o) - \rho_a$
Δ_{si}	$= \rho_a(o) - \rho_{si}$
ρ	density
$\rho_a(y)$	ambient density at y
ρ_{si}	density of ith solid
ϵ	density gradient
σ_x^2	x-variance of diffusing pool
σ_z^2	z-variance of diffusing pool
σ_{xz}	covariance of diffusing pool

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SECTION I

INTRODUCTION

One method of disposal of concentrated wastes such as dredge spoil, sewage sludge and industrial wastes is to barge it out to sea and dump it overboard. Several distinct schemes for the discharge of the waste cargo from the barge into the sea can be envisioned. These include: a) dumping the waste load from a bottom opening hopper barge, b) discharging it by pumping the waste through nozzles at the bottom of the barge and c) discharging it into the barge wake. A more detailed review of current practice and typical waste characteristics can be found in Clark, et al (1971).

As a first step in the overall evaluation of the environmental impact of this practise, it is necessary that the mechanics of dispersion of the discharged waste be analysed. The analysis must include the determination of the concentration of the waste material in suspension, in solution and the distribution of disposed solids, either floating at the surface or settled on the ocean floor.

It is the primary purpose of the present study reported herein to develop a mathematical model for the analysis of dispersion of the disposed waste in the ocean environment. The model is detailed in Section III of this report. A computer program based on this model is also included as Appendix A in this report. Based on this model, the fate of the waste can be determined given the waste characteristics, the ocean environmental conditions and the method of disposal.

In addition, a series of preliminary laboratory experiments have been performed and reported in Section IV. The primary purposes of these experiments are the establishment of the adequacy of the mathematical model and the verification of the important assumptions made. Comparison of the experimental results with the predictions based on the mathematical model is presented in Section V.

A sequence of example cases have been analysed based on the model and the results are presented in Section VI and Appendix B.

SECTION II

CONCLUSIONS AND RECOMMENDATIONS

In this study, a mathematical model has been developed to predict the physical fate of wastes discharged from barges. A computer program has also been written based on the mathematical model. In addition, a set of preliminary laboratory experiments were performed to verify and supplement the mathematical model. Based on the study, the following conclusions and recommendations are made.

1) The general behavior of the discharged waste, with or without solid constituents of the type used in the experiments, behaves similarly.

2) The comparison between the experimental results and the theoretical predictions is good.

3) The mathematical model requires the knowledge of various empirical coefficients. A set of suggested values are built into the computer program. However, as better knowledge becomes available through experiments, these may be modified. It is recommended that experiments be performed in the future to better define these coefficients.

4) With the built in coefficients, the model is believed adequate in predicting the physical dispersion and settling characteristics of typical solid wastes over the long run when a number of discharges are made even though the detailed description for each single discharge may not be as accurately predicted until the coefficients are better defined.

5) A set of representative runs has been made using the numerical model and presented in Section VI. However, due to the large number of parameters, in no way can these runs be considered a parametric study. It is recommended that a parametric study be performed to obtain a complete description of the dependence of the result on the parameters.

6) While the basic mathematical model for long term diffusion allows the ambient conditions such as the diffusion coefficients, and currents to be functions of time, they are treated as only functions of the vertical coordinate in the computer program. It is recommended therefore that the program be modified to allow them to be functions of time so that the effects of temporal variations, such as encountered in tidal currents, can be obtained.

7) The model as developed assumes that the waste will undergo a phase of descent and that the gross density of the waste is larger than the ambient. While in practice this should always be the situation lest the waste would undesirably spread on the surface, the model can and should be modified to include this possibility.

8) In the model, after the descent phase, the waste is directed by the program to either a) collapse if the local ambient is stratified or if the bottom is encountered, or b) go directly to the long term diffusion phase. Due to the settling of solid particles, the waste pool may reach the end of the descent phase in a uniform ambient with or without first passing through a density gradient. Depending on the latter condition, going directly to long term diffusion may or may not be valid. The user of the model must exercise some judgement as to whether or not to slightly modify the input density stratification to ensure a collapse phase.

9) Based on the results presented in Section VI, the method of discharge in Barge Operation 1 results in the most likelihood of the waste cloud reaching the bottom even if there exists a fairly strong pycnocline. In Barge Operations 2 and 3, a relatively weak pycnocline is usually sufficient to arrest the vertical descent of the waste plume. This phenomenon should be further explored in a detailed parametric study since it has practical implications.

10) One of the main drawbacks of the method of moments used in this study for the long term diffusion phase is the fact that the ambient conditions cannot be functions of horizontal position. While strictly speaking, there is no way to overcome this without abandoning the advantages of the method of moments, physically, it may be argued that as long as the characteristic horizontal scale of the variation of ambient conditions is large compared with the size of the diffusing waste pool, horizontal variation of the ambient condition can be allowed to provide at least a first approximation. It is recommended that this capability be incorporated in the model.

SECTION III

DEVELOPMENT OF THE MATHEMATICAL MODEL

In this section, a mathematical model will be developed for the prediction of the dispersion and settling of waste material discharged from barges into the ocean environment. Only the physical aspects of the phenomenon will be analysed since the chemical, biological and ecological aspects are beyond the scope of the present investigation.

In this investigation, three different modes of operation for the disposal of waste from barges are considered, namely 1) simple over board dumping, 2) discharge through a nozzle under the barge bottom and 3) discharge into the barge wake. In spite of the apparently different methods of disposal, the waste material is ultimately either settled to the bottom or mixed into the ambient. The dispersion process in each of the three modes can be roughly divided into three stages. In the early stage, the phenomenon is dominated by the effects of the initial momentum and buoyancy of the discharge. In the final stage the waste material is essentially dynamically passive and subject to diffusion due to the effects of ambient turbulence. In between, there is a transition phase between the two stages. In the following, the properties of the waste material and the ambient conditions will first be discussed, then mathematical models will be developed for each barge operation and for each stage of the mixing process, finally a numerical solution to the whole problem and a computer program will be presented.

3.1 Properties of Waste Material

According to Clark et al. (1971), the most important waste materials presently being disposed by barges are dredge spoil, sewage sludge and industrial wastes. The dredge spoil can be organic or inorganic solids with or without contamination from fertilizers, chemicals, pesticides as well as a variety of industrial wastes. Among the ecological effects of the discharge of dredge spoil found are i) a temporary reduction in fish abundance and dissolved oxygen, ii) an increase in turbidity, iii) an increase in the level of pesticide concentration in fish and iv) an increase in nutrients in the water. For the sewage sludge, the inherent public health hazard and the potential for build up of organic solids on the ocean bottom are most significant. Industrial wastes vary widely in their properties, depending on their particular origin. In addition, there are other waste materials which may be discharged from barges such as radioactive wastes, garbage and refuse.

Dredge spoil constitutes by far the largest percentage of waste material dumped from barges. For example, in 1968, it contributes to 80% of all such discharges. The characteristics of dredge spoil for the Great Lakes region is summarized on Table 3-1. It is observed that most of the solid particles are in the silt $(4\mu < d < 63\mu)$ and sand $(63\mu < d < 2mm)$ range. The average bulk density is 1.33 gm/cc, while the average settling velocity is 0.518×10^{-4} fps with the solid concentration about 40%. Physical properties of sewage sludge can vary with the nature of the treatment process as well as its age and storage. It can be visualized that the fall velocity of the solid particles in sludge would be smaller than that of the dredge spoil particles.

In the formulation of the mathematical model, the waste material is considered to consist of two phases, a solid phase and a liquid phase. The solid phase is characterised by a discrete set of fall velocities, solid densities and concentrations while the liquid phase is assumed to be miscible with the ambient ocean water. While the phenomena of flocculation, ablation, and hindered settling are not explicitly included in the analysis, they are in essense partially incorporated in the model in that several fall velocities and solid densities are permitted in the numerical model simultaneously, the number being limited only by the availability of storage locations and computation time.

The bulk density of the waste is assumed to be larger than the ambient. Were this not the case, the waste concentration can be expected to be relatively high near the surface leading to an undesirable situation.

TABLE 3.1

GREAT LAKES DREDGING SPOIL CHARACTERISTICS*

Location	Percent Solids	Average Density gm/ml	Settling Velocity ft/hr a/	Average Percentage by Weight Gravel d>2 mm	Sand 63u<d<2mm	Silt 4u<d<63u	Clay d<4u
Buffalo	37.0	1.27	0.068	0.1	18.4	70.6	10.7
Calumet	40.7	1.33	0.144	0.2	20.8	48.5	31.1
Cleveland	44.9	1.36	0.201	1.9	9.1	72.3	16.0
Green Bay	43.0	1.37	0.103	10.6	29.1	26.2	34.1
Indiana	35.2	1.23	0.150	1.9	29.2	53.1	13.8
Rouge River	43.7	1.28	0.290	1.9	40.9	35.9	20.7
Sodus Bay	53.1	1.51	0.506	0.0	50.8	41.2	8.1
Toledo	39.0	1.30	0.023	0.8	10.9	47.2	41.1

a/ Based on 30 minute settling

	Dredge Samples
Buffalo	22.9
Cleveland	22.3

---

* from Clark et al (1971)

3.2 Ambient Conditions

Knowledge of pertinent aspects of the ocean environment is essential for predicting the fate of waste material discharged from a barge into the ocean environment. These include the structures of ocean density, ocean current and ocean turbulence.

3.2.1 Ocean Density Structure

The density of sea water depends upon temperature, salinity and pressure. In the ocean, the potential density is often inhomogeneous due to variations in temperature and salinity. A typical ocean density profile is shown in Figure 3.2.1. In general, the density of sea water increases with depth. The ocean is then said to be stably density stratified.

The surface layer in the ocean is characterized by relatively low salinity (35^{o}/oo) and high temperature (20^{o}C). The density is fairly uniform within this so-called "mixed layer" because of wind induced agitation and vertical circulation induced by evaporation and temperature reversals across the free surface. The thickness of the mixed layer varies depending on local wind and weather conditions but is typically of the order of a few hundred feet.

The ocean depths are characterized by higher salinity (37^{o}/oo) and lower temperature (2^{o}C). It is relatively stagnant and much less disturbed than the mixed layer. In this deep layer, a moderate or weak density gradient is ususally maintained. According to Defant (1961), the density gradient $\varepsilon [= - 1/\rho_o (d\rho_a/dy)]$ in the deep layer is roughly in the range of 10^{-6} to 10^{-7}/m.

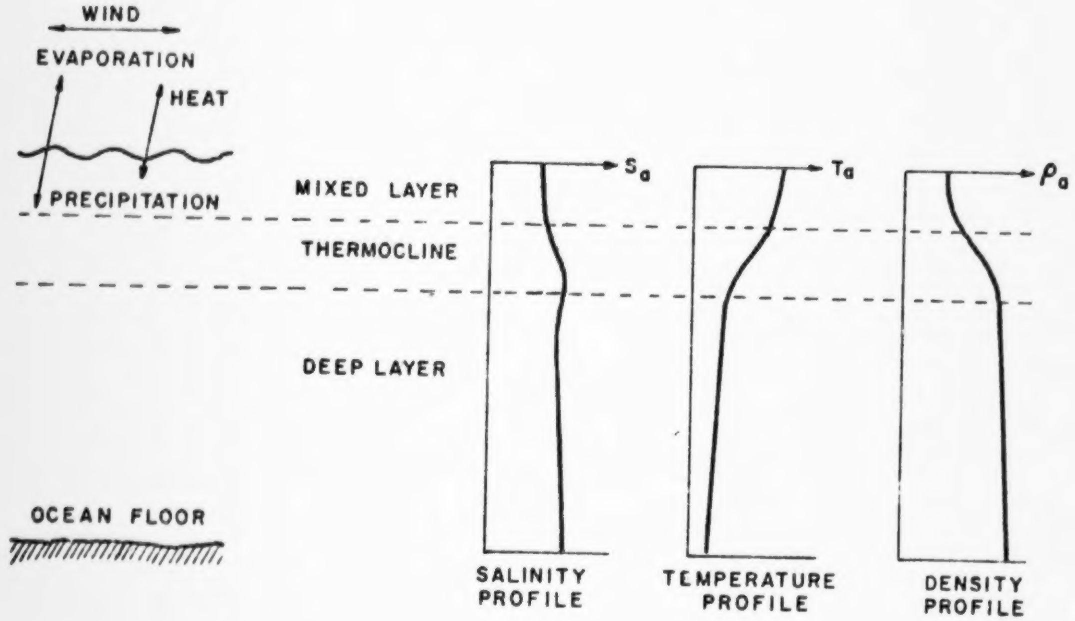


Figure 3.2.1

Ocean Density Structure

Between the mixed and the deep layers there is a transition layer called the "thermocline" with a relatively sharp density gradient. Such a layer acts as an efficient barrier to the vertical exchange between the surface and deep layers of the ocean. The thickness and depth of the thermocline vary greatly with season and location. The value of ϵ may reach $10^{-3}/m$ in the thermocline.

3.2.2 Ocean Currents and Turbulence

The ocean is constantly in motion being agitated by forces from different origins. Ocean currents are generated by:

a) geostrophic forces associated with the steady state density field in the ocean;

b) surface tidal forces;

c) internal tidal forces;

d) local wind-induced forces (Ekman wind drift) which are restricted to relatively shallow depths; and

e) wave induced forces.

The types of currents generated by a), b), c) and e) are the most important in the present problem. Current profiles can be derived theoretically in some cases; e.g., cases d) or e). In reality, the ocean currents are always a result of a combination of the forces listed above. Thus, there is no standard velocity profile that is applicable under all ocean conditions. However, the currents in the ocean are mostly horizontal.

Measurements of ocean currents are made difficult by instrumentation limitations. Data on the ocean currents are mostly limited to the surface and in the surface mixed layer. Current velocities here often reach 1 fps or more. Information on the current velocity in the thermocline or the deep layer is scare. Recently, velocity measurements carried out in the deep layers showed the existence of velocities of the order of 0.1 fps.

The distinction between ocean current and turbulence is often not clear until the mode of averaging is specified. In other words, the length scales used in the averaging process must be chosen based upon the scale of the interested phenomenon. Turbulence in the ocean may be visualized as the coexistence of eddies of various sizes. In the present study eddies much greater in size than that of the diffusing pool should be regarded as currents. For a much larger pool, these eddies should be considered as turbulence.

The detailed characteristics of turbulence in the ocean is almost entirely lacking. The difficulty in instrumentation for measuring turbulence in the ocean is tremendous. Progress is beginning to be made in direct measurement of ocean turbulence.

In analysing ocean diffusion problems, the turbulent transport is often represented by semi-empirical diffusion coefficients defined as follows:

$$K_x = - \frac{\overline{u'C'}}{\frac{\partial \overline{C}}{\partial x}} + D_x$$

$$K_y = - \frac{\overline{v'C'}}{\frac{\partial \overline{C}}{\partial y}} + D_y \qquad (3.2.1)$$

$$K_z = - \frac{\overline{w'C'}}{\frac{\partial \overline{C}}{\partial z}} + D_z$$

where K_x and K_z are the horizontal diffusion coefficients K_y is the vertical diffusion coefficient $-\overline{u'C'}$, $-\overline{v'C'}$, $-\overline{w'C'}$ are turbulent transport quantities in (x, y, z) directions, $\overline{C}$ is the mean concentration of the transported material, D_x, D_y, D_z are the molecular diffusion coefficients.

Equation (3.2.1) defines the diffusion coefficients in such a way that they represent the combined effects of turbulent and molecular transport. Generally, molecular transport is negligible in comparison with the turbulent counterpart. However, in some instances, for example, when vertical turbulence is completely suppressed by a strong density stratification, the vertical transport may entirely be due to molecular diffusion; i.e., $K_y = D_y$.

The nature of these diffusion coefficients will now be disucssed. Note that the values of these coefficients were not usually determined by measuring turbulent transport quantities as given by Equation (3.2.1) but from observations on some gross diffusion characteristics such as the rate of spread of dye patches.

The vertical diffusion coefficient K_y is usually several orders of magnitude smaller than the horizontal diffusion coefficients because of the presence of stable density stratification and boundaries imposed by the free surface and the bottom of the ocean. The nature of the vertical diffusion coefficient is different from its horizontal counterpart and thus they are discussed separately.

3.2.3. Horizontal Diffusion Coefficient -- K_x (or K_z)

Most investigators concentrated on the investigation of horizontal turbulent diffusion in the ocean. Dye or other tracer objects were released and the size of the dispersing patch was observed as it grew with time. Sometimes existing materials in the ocean were used as tracers. Horizontal diffusion coefficients were then derived based upon diffusion models disregarding both current shear and vertical transport. Extensive information in this respect is available in the literature. [e.g., Stommel (1949), Richardson and Stommel (1948), Olson and Ichiye (1959), Munk, Ewing and Revelle (1949), Gunnerson (1960), Ichiye (1962), Okubo (1962), Bowden (1962), Joseph and Sendner (1962), Foxworthy, Tibby and Barsom (1966), and Snyder (1967)].

The values of horizontal diffusion coefficients obtained in the ocean ranged from 5×10^2 to 4×10^8 cm^2/sec. Most values were obtained at the ocean surface. The values of K_x (or K_z) were found to increase with the size of the diffusing patch L as shown in Figure 3.2.2. Although data scatter is significant, the general trend follows a 4/3 power law: i.e.,

$$K_x = A_L L^{4/3} \qquad 10^{-1}\text{ft} \le L \le 10^8 \text{ ft} \qquad (3.2.2)$$

where A_L is a constant called dissipation parameter (in fps system: ft$^{2/3}$/sec and in cgs system: cm$^{2/3}$/sec).

The 4/3 power relation has some theoretical basis according to Kolmogoroff's similarity hypotheses [Batchelor (1950)]. However, Equation (3.2.2) is strictly empirical since its range extends well beyond the limiting scale of the Kolmogoroff inertial subrange. The value of A_L varied from 5×10^{-3} to 1.5×10^{-4} ft$^{2/3}$/sec.

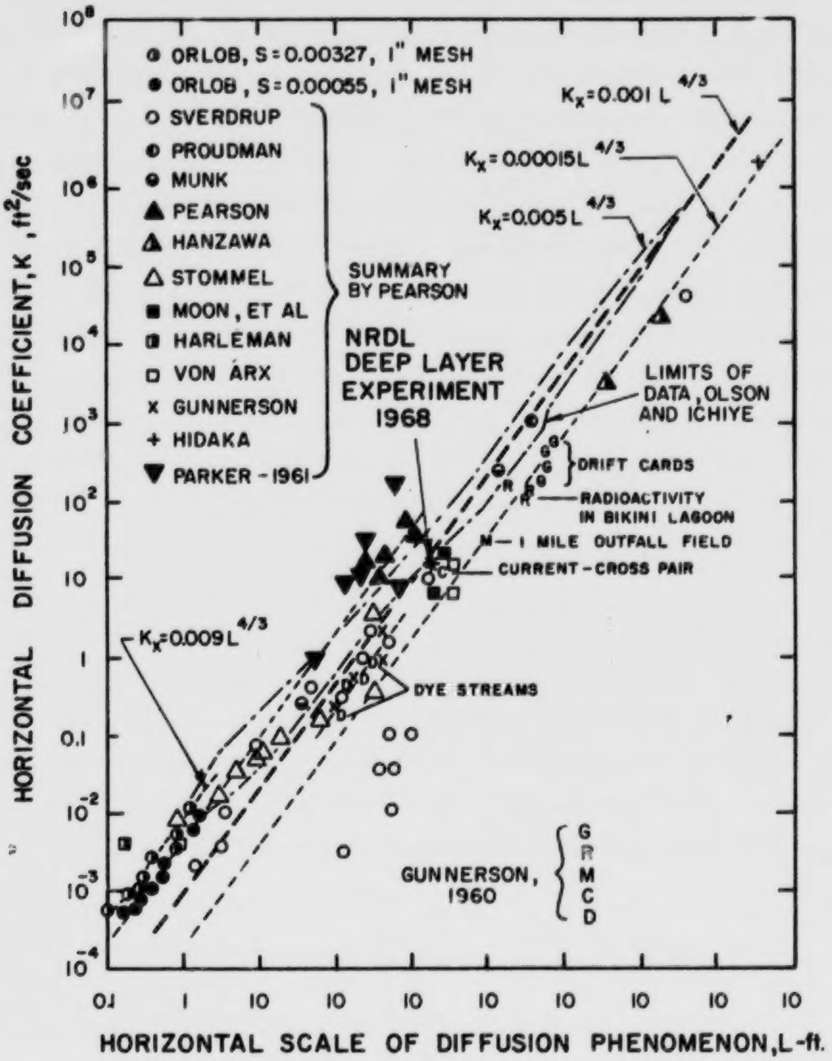


Figure 3.2.2 Horizontal Diffusion Coefficient as a function of Horizontal Scale (from Orlob 1959)

It is expected that as the depth increases and approaches the thermocline, the horizontal turbulent transport might decrease. Thus one might expect A_L to decrease with increasing density gradient. Munk, et. al. (1949) found that in Bikini Lagoon at 50 m depth, the value of horizontal diffusion coefficient was only one-third of that observed near the surface. However, in this case, an error might have been introduced since horizontal exchange was calculated separately from the vertical exchange. Snyder (1967) found that at 9 ft depth the value of A_L drops to one quarter of the value at the free surface (0.00017 vs 0.00065 $ft^{2/3}/sec$). However, the tracer objects used in the 9 ft depth test appear to respond somewhat slowly to the turbulence which might have caused such fast drop-off. Nevertheless at present there is no definitive determination of the variation of horizontal diffusion coefficient as a function of ambient density structure.

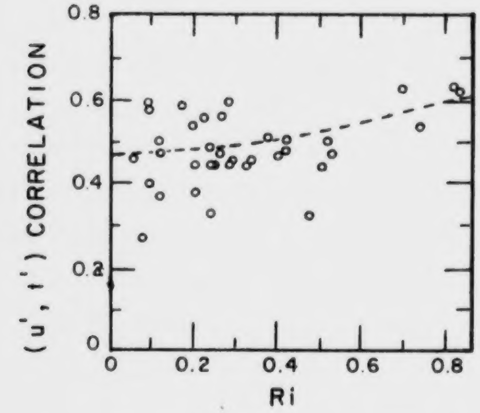
In general, the horizontal transport is expected to be less affected by the density stratification than the vertical transport. Based upon Webster's (1964) measurement in a uniform shear flow with constant temperature gradient generated in a laboratory wind tunnel, the horizontal transport ($-\overline{u't'}$), as shown in Figure 3.2.3a, was found to be unaffected by the increase of the Richardson number, R_i, defined as:

$$R_i = \frac{\varepsilon g}{\left(\frac{du_a}{dy}\right)^2} \qquad (3.2.3)$$

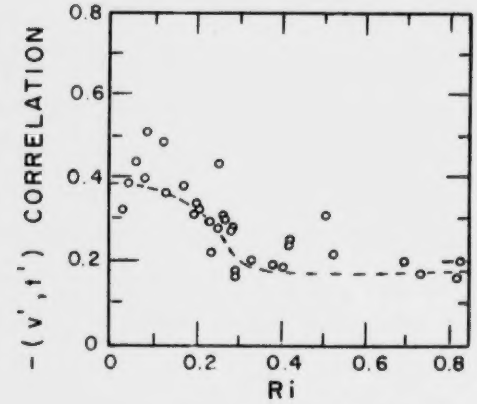
where ε is the density gradient

$\frac{du_a}{dy}$ is the velocity gradient

On the other hand, he found that the vertical transport ($-\overline{v't'}$) decayed rapidly with R_i as shown in Figure3.2.3b. Therefore, at present, a constant value of A_L (independent of depth) may be used as a first approximation. It must be reiterated that in the past determinations of these horizontal diffusion coefficients, the effects of vertical exchange



a) HORIZONTAL TRANSPORT



b) VERTICAL TRANSPORT

Figure 3.2.3 Variation of Transport Rates as Functions of Richardson Number R_i, (u' :horizontal velocity fluctuation, v' : vertical velocity fluctuation, t' : temperature fluctuation; from Webster, 1964)

and current shears were neglected. Thus the values of K_x obtained include implicitly such effects.

It is interesting to note that if an experiment is performed at the sea surface with floating tracer objects, the objects stay at the surface and are not subject to either vertical exchange or current shear effects. For these experiments, effects of shear and vertical exchange were automatically excluded. However, results from such experiments were not much different from the other sets of data and is in fact within the range of scattering. Therefore, it is very likely that values derived in previous experiments are close to the cases with zero shear effects.

3.2.4 Vertical Diffusion Coefficient

The vertical diffusion coefficient in the ocean is generally much smaller than the horizontal diffusion coefficient because of the suppression of vertical transport by stable density stratification. Values of vertical diffusion coefficients have been obtained by numerous investigators under various ocean conditions. These are summarized in Table 3.2.1. These values ranged from 10^{-2} to 300 cm^2/sec. (Note that 1 $cm^2/sec = 1.1 \times 10^{-3} ft^2/sec$.) They are much smaller than horizontal diffusion coefficients as discussed previously. These K_y values were obtained by using various methods including observations of salinity and temperature changes or diffusion of tracer substances in the ocean. There is no apparent universal law or values for K_y. Generally, the vertical diffusion coefficient has its maximum at the surface and decreases as the depth increases. This is as expected since the surface layer is subjected to wind agitation and convective instability. That is, in fact, the reason it remains relatively well mixed. As pointed out by Koczy (1960), the vertical diffusion coefficient decreases as it approaches the thermocline because of the increase of density stratification. The value of K_y may decrease close to its molecular value (for heat: 1.5×10^{-3} cm^2/sec and for NaCl: $1.3 \times$

TABLE 3.2.1

SUMMARY OF VALUES OF VERTICAL DIFFUSION COEFFICIENT K_y IN THE OCEAN

Note: Molecular diffusivity for heat: 1.5×10^{-3} cm^2/sec (at 20°C, 1 atm)
salt: 1.3×10^{-5} cm^2/sec (at 20°C, 1 atm)

Current or oceanic region	Depth of layer (m)	Vertical Diffusion Coefficient K_y (cm^2/sec)	Reference	
Philippine Trench	5000-9788	2.0-3.2	Schmidt, 1917	*
Algerian Coast	0- 20	35-40	Schmidt, 1917	
Mediterranean	0- 28	42	Schmidt, 1917	
California Current	0- 200	30-40	McEwen, 1919	
Caspian Sea	0- 100	1-3	Stockman, 1936	
Barents Sea	-----	4-14	Subov, 1938	
Bay of Biscay	0- 100	2-16	Fjeldstad, 1933	
Equatorial Atlantic Ocean	0- 50	320	Defant, 1932	
Randesfjord	0- 15	0.1-0.4	Jacobsen, 1913	
Schultz Grund	0- 25	0.04-0.74	Jacobsen, 1913	
Kuroshio	0- 200	30-80	Sverdrup-Staff, 1942	
Kuroshio	0- 400	7-90	Suda, 1936	
Southern Atlantic Ocean	400-1400	5-10	Defant, 1936	
Arctic Ocean	200- 500	20-50	Sverdrup, 1933	
Carribean Sea	500- 700	2.8	Seiwell, 1938	
South Atlantic Ocean	3000-Bottom	4	Defant, 1936	
South Atlantic Ocean	Near Bottom	4	Wattenberg, 1935	
West Atlantic Trough (50°S to 10°N)	Near Bottom	7-50	Wüst, 1955	**
North Atlantic Indian Ocean Pacific Ocean	Near Bottom	4-30	Koczy, 1956	**
Tidal Channel (Mersey estuary and Irish Sea)	0- 20 (bottom)	2-40	Bowden, 1965 (with R_i from 0.1 to 2.0)	
Near Cape Kennedy, Florida	Surface Layer	19 (in August) 1.3 (in Summer	Carter and Okubo, 1965	
Bikini Lagoon	0- 50 (bottom)	260	Munk, Ewing and Revelle, 1949	
Coast of Denmark		0.05-1	Harremoes, 1967	
California Coast		0.1-10	Foxworthy, Tib[illegible] and Barsom, 1966	***
-------	4	15-180 (at wind force 3-4)	Stommel and Woodcock, 1951	****

* As given by Defant, 1961
** As given by Bowden, 1962
*** As given by Harremoes, 1967
**** As given by Wiegel, 1964

10^{-5} cm^2/sec for sea water at 20°C and 1 atm) if vertical turbulence collapses completely. The value of K_y may increase somewhat from the thermocline to the deep layer as indicated by Koczy (1960). Variation of K_v in the ocean remains to be investigated more extensively. Present day methods of determination are based upon variation of the vertical spreading of a certain substance. In the region of small vertical diffusion coefficient, a long observation period is required to achieve a moderate accuracy in determining K_y. In the future, direct measurement of the vertical transport rate $(-\overline{v'C'})$ may become feasible as instrumentation improves.

The vertical transport decreases as R_i increases. For $R_i = 0$, i.e., no density gradient, the transport rate is at its maximum. The dependence of K_y as a function of R_i is a basic problem in fluid mechanics which should be fully investigated. When such a relation is known, it can be used to estimate K_y in the ocean if ε and du/dy are known.

A summary of results of various investigators is as shown in Table 3.2.2. These relationships all show correct trend but are all different in quantitative prediction. This remains to be clarified in the future. Among these eight proposed equations, all have right asymptotic behavior for $R_i=0$, i.e., the neutral case, except Kolesnikov et. al. (1961) and Harremoes (1967). The equations proposed by Kolesnikov et, al., and Harremoes are based upon the density gradient (ε) only. The equations porposed by Holzman (1943) and Yamamoto (1959) show that there is a limiting value of R_i, or a critical Richardson number, at which K_y vanishes. The values of the constant β in these equations have to be determined before these equations can be applies. A major difficulty is the lack of accurate relevant data on K_y.

For further discussion on the diffusion coefficients, the reader is referred to Koh and Fan (1969).

TABLE 3.2.2

SUMMARY OF FORMULAS ON CORRELATION OF VERTICAL DIFFUSION COEFFICIENT K_y WITH RICHARDSON'S NUMBER R_i (OR DENSITY GRADIENT ϵ)

Note: K_{y0} : K_y at $R_i = 0$, i.e., the neutral case β : proportionality constant varies from case to case

Rossby and Montgomery (1935)*	$K_y = K_{y0}(1 + \beta R_i)^{-1}$	
Rossby and Montgomery (1935)*	$K_y = K_{y0}(1 + \beta R_i)^{-2}$	
Holzman (1943)*	$K_y = K_{y0}(1 - \beta R_i)$	$R_i \leq \frac{1}{\beta}$
Yamamoto (1959)*	$K_y = K_{y0}(1 - \beta R_i)^{1/2}$	$R_i \leq \frac{1}{\beta}$
Mamayev (1958)*	$K_y = K_{y0}\, e^{-\beta R_i}$	
Munk and Anderson (1948)**	$K_y = K_{y0}(1 + \beta R_i)^{-3/2}$ $\beta = 3.33$ based upon data by Jacobsen (1913) and Taylor (1931)	
Harremoes (1968)	$K_y = 5 \times 10^{-3} \times \epsilon^{-2/3}\ \mathrm{cm^2/sec}$ note: ϵ in $\mathrm{m^{-1}}$; approximate experimental range $5\mathrm{x}10^{-9} < \epsilon < 15\mathrm{x}10^{-5}\mathrm{m}^{-1}$	
Kolesnikov, et al (1961)***	$K_y = K_{y\,min} + \frac{\beta}{\epsilon}$ in $\mathrm{cm^2/sec}$ $K_{y\,min}$ and β are empirically determined to be: $K_{y\,min} = 12$, $\beta = 8.3 \times 10^{-5}$ (1958 and 1960 observations) $K_{y\,min} = 2$, $\beta = 10.0 \times 10^{-5}$ (1959 observations)	
Koh and Fan (1969)	$K_y = 10^{-4}/\epsilon$ (K_y in $\mathrm{cm^2/sec}$; ϵ in $\mathrm{m^{-1}}$) $4 \times 10^{-7} \leq \epsilon \leq 10^{-2}\mathrm{m}^{-1}$	

* As given by Okubo (1962)

** As given by Bowden (1962)

*** The formulas presented in the translated version are apparently erroneous.

3.3 Barge Operation 1 - Simple Over-Board Dumping

Perhaps the simplest way of discharging waste material into the ocean from a barge is a simple over-board dumping. After its release from the barge, the cloud of waste material will descend by virtue of its momentum and buoyancy. As the cloud moves downward it will push the ambient fluid around it, experience drag from the flow field, while entraining some of the surrounding fluid. During this process the solid particles inside the cloud tend to settle out of it. If the ambient is density stratified, the cloud could reach a neutrally buoyant position and oscillate about it. At this point the vertical motion is much reduced and the effects of ambient density stratification become dominant with the result that the cloud tends to collapse vertically and spread out horizontally seeking a hydrostatic equilibrium with the ambient fluid.

If the waste material consists of fluid only, then it can be treated as a buoyant element (sometimes termed a thermal by meteorologists). Buoyant thermals have been studied in a still water tank by Scorer (1957). Both Scorer (1957) and Woodward (1959) reported on the flow field in and around a thermal. Their description can be summarized schematically for the barge operation 1 as shown in Figure 3.3.1. The buoyant element is seen to have the shape of a hemisphere reminiscent of a vortex ring. The rise of thermals in a stratified still environment has also been investigated by Morton, Taylor and Turner (1956) and buoyant vortex rings have been investigated by Turner (1957 and 1960). Other related articles on this subject include Richards (1961, 1965), Turner (1963), Hall (1962) and Turner (1966). More recently Koh and Fan (1968) applied the thermal model to the prediction of the radioactive debris distribution subsequent to a deep underwater nuclear explosion. Their model included both density stratification and shear current. In the same report, Koh and Fan (1968) further analyzed the dynamic collapse of a neutrally buoyant cloud in a quiescent stratified ambient assuming no entrainment.

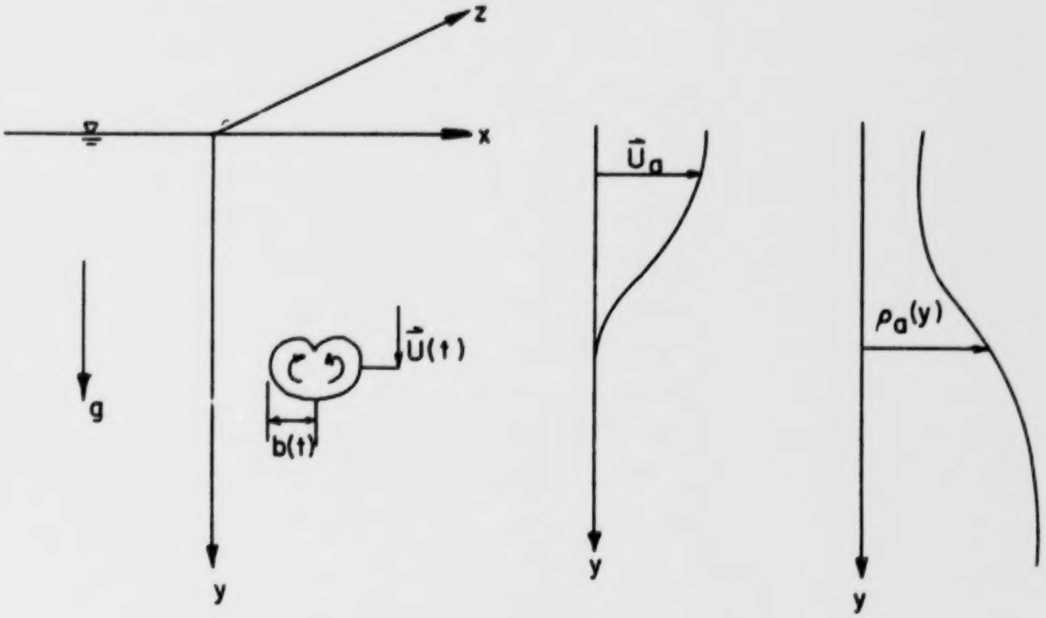


Figure 3.3.1 Schematic Definition Sketch

In this study, Koh and Fan's approach is further extended to apply to a waste cloud with (or without) solid particles in it. In the dynamic collapse phase, their model is extended to include entrainment and shear current.

3.3.1 Convective Descent

After being released from the barge, the waste material mass will be assumed to retain its identity as an entity as it convects. Settling of solid particles is allowed as the situation occurs. A mean linear size and mean velocity will be defined for the element as $b(t)$ and $\vec{U}(t)$ where t is the time. Let $\rho(t)$ be the mean density of the element and $\rho_a(y)$ the ambient density. Let $\vec{U}_a(y)$ be the ambient current, assumed horizontal and function only of vertical coordinate y (See Figure 3.3.1). The characteristics of the element are assumed similar at all stages of its motion, and to retain the shape of a hemisphere. The various solid particles inside will be assumed to have densities $\rho_{si}(i=1,2,\ldots,n)$. Because of size distribution, the solids are further characterized by their fall velocities w_{sij}, $(i=1,2,\ldots,n;\ j=1,2,\ldots,m)$. For each specific density ρ_{si} and fall velocity w_{sij} the concentration is designated C_{sij}.

Then the equations governing the motion are:

Conservation of Mass:

$$\frac{dV}{dt} = E\rho_a - \sum_i \sum_j S_{ij}\rho_{si} \qquad (3.3.1)$$

Conservation of Momentum:

$$\frac{d}{dt}\vec{M} = F\vec{j} - \vec{D} + E\rho_a\vec{U}_a - \sum_i \sum_j S_{ij}\rho_{si}\vec{U} \qquad (3.3.2)$$

Conservation of Buoyancy:

$$\frac{dB}{dt} = E\Delta_f - \sum_i \sum_j S_{ij}\Delta_{si} \qquad (3.3.3)$$

Conservation of Vorticity:

$$\frac{dK}{dt} = -A\epsilon \qquad (3.3.4)$$

Conservation of Solid Particles:

$$\frac{d}{dt} P_{ij} = -S_{ij} \qquad (3.3.5)$$

where

$V = \rho \frac{2}{3}\pi b^3$

total mass in the cloud

$E = 2\pi b^2 \alpha \left| \vec{U} - \vec{U}_a \right|$

entrainment in volume

$S_{ij} = \pi b^2 \left| w_{sij} \right| C_{sij} (1 - \beta_{ij})$

settled solids in volume

$\vec{M} = C_M \rho \frac{2}{3}\pi b^3 \vec{U}$

momentum

$$F = \frac{2}{3}\pi b^3 g(\rho - \rho_a)$$

buoyancy force

$$D_x = \frac{1}{2}\rho_a C_D(.5\pi b^2)\left|\vec{U} - \vec{U}_a\right|(u - u_a)$$

drag force in x-direction

$$D_y = \frac{1}{2}\rho_a C_D \pi b^2\left|\vec{U} - \vec{U}_a\right| v$$

drag force in y-direction

$$D_z = \frac{1}{2}\rho_a C_D(.5\pi b^2)\left|\vec{U} - \vec{U}_a\right|(w - w_a)$$

drag force in z-direction

$$B = \frac{2}{3}\pi b^3(\rho_a(o) - \rho)$$

buoyancy

$$A = Cb^2 g \frac{1}{\rho_a(o)}$$

coefficient for vorticity dissipation

$$\varepsilon = \frac{d\rho_a}{dy}$$

ambient density gradient

$$\Delta_f = \rho_a(o) - \rho_a$$

ambient density difference between that at the free surface and that at the position of the centroid of the cloud

$$\Delta_{si} = \rho_a(o) - \rho_{si}$$

density difference between that at free surface and the solid particles

$$P_{ij} = \frac{2}{3}\pi b^3 C_{sij} \tag{3.3.6}$$

solid volume in the cloud

In the above equations, α is the entrainment coefficient, β_{ij} is the settling coefficient, $\vec{j}$ is a unit vector in the vertical direction, C_D is the drag coefficient, C_m is the apparent mass coefficient, ρ_a (o) is the density at the free surface, K is the vorticity, and C is a vorticity dissipation coefficient (equals to 3, according to Turner, [1960]).

In the above formulation, the entrainment is assumed to be proportional to the relative velocity between the element and the surrounding fluid and to the area of the hemispherical front. The entrainment coefficient α should in fact depend on the properties of the cloud and the ambient fluid and the turbulence structure inside and outside the convective element. α has been experimentally determined to be approximately 0.25 by Scorer (1957) and Richards (1961). Generally, it is found to be constant for each single experiment, but tends to vary significantly among experiments. In one rare experiment, Richards (1961) even observed α to change abruptly from 0.15 up to 0.62 during convection. In studying the motion of a vortex ring, Turner (1960) found that

$$\alpha = \frac{B}{2\pi g C_1 K^2}, \qquad (3.3.7)$$

by assuming similarity where C_1 was found to be 0.16. When waste material is dumped from a barge, vorticity can be generated from the initial momentum and buoyancy. However, as the cloud descends the vorticity becomes zero, Turner's assumption cannot hold. Since α is expected to approach α_o found in turbulent thermals, it seems reasonable to postulate that the dependence of α on B and K might be of the form

$$\alpha = \alpha_o \left(\tanh \left(\frac{B}{2\pi g C_1 K^2 \alpha_o} \right)^2 \right)^{1/2} \qquad (3.3.8)$$

The only justification for Equation (3.3.8) is that it tends to the correct limits. Thus when K is large, α approaches Turner's assumption, while when K is small α approaches α_o. However this expression has not been verified by experiment and is presented here only as a conjecture.

The mechanism of settling from a convecting cloud is another complicated subject that has not been thoroughly investigated. As observed in the related research of buoyant thermals, the convective cloud is often a weak vortex, and the turbulence inside the cloud is related to the descending velocity of the cloud. From dimensional analysis, it may be argued that

$$f\,(q_{ij},\ w_{sij},\ v,\ b,\ \rho_{si},\ C_{sij},\ C_s\ ) = 0$$

where q_{ij} is mass rate settling out of the cloud and C_s is $\sum_{i=1} \sum_{j=1} C_{sij}$, the total concentration. Thus

$$\frac{q_{ij}}{w_{sij}\,\rho_{si}\,b^2} = g\left(\frac{v}{w_{sij}},\ C_{sij},\ C\right) \qquad (3.3.9)$$

Equation (3.3.9) shows that the dimensionless mass rate of settling is a function of the ratio of the descending velocity and the fall velocity of the solid particle, the concentration of each group and the total concentration. At high concentrations, hindered settling could occur. Now equation (3.3.9) can be further simplified to the following form

$$q_{ij} = w_{sij}\,\pi\,b^2\,\rho_{si}\,C_{sij}\,(1 - \beta_{ij}) \qquad (3.3.10)$$

where β_{ij} is defined to be a settling coefficient which depends on $\frac{v}{w_{sij}}$, C_{sij} and C. Although the functional form is not available at present,

β_{ij} is expected to be between 0 and 1, the extreme representing the two cases of settling freely or no settling. Discussion of several situations will help in the understanding of β_{ij}. If v is zero and the concentration is low, the solid particles would settle freely and hence β_{ij} is 0. For particles with positive fall velocity, and for $v \geq -w_{sij}$, it can be visualized that even if a solid particle does settle out of the cloud, it will be overtaken by the cloud, i.e., no settling will occur and $\beta_{ij} = 1$. However, when the cloud is moving opposite to the direction of settling, i.e., floating particles in a descending cloud or sinking particles in a rising cloud, the criteria for β_{ij} are less obvious. If v is relatively large, the solids are envisioned to be trapped in the cloud by turbulence, and if v is small settling will occur. The actual functional form of β_{ij} must be determined by future experimental investigation. In the present model, β_{ij} is assumed to be of the form

$$\beta_{ij} = \begin{cases} 0 & \text{if} \quad |v/w_{sij}| < 1 \\ \beta_o & \text{if} \quad |v/w_{sij}| \geq 1 \end{cases}$$

where β_o is a constant which is assumed known.

The drag coefficient, C_D, is in general a function of Reynolds number, hence it depends on b and $|\vec{U} - \vec{U}_a|$. In the convective phase C_D is chosen to be 0.5. C_M, the apparent mass coefficient should be in the range $1 > C_M > 1.5$.

In Equations (3.3.4) the decay of vorticity is assumed to depend on the ambient stratification only. In fact, the vorticity decay is likely to be much more complicated and the formulation is therefore subject to change when better knowledge is acquired.

3.3.2 Dynamic Collapse

In undergoing the convective descent phase, the waste material cloud usually gains a significant amount of mass and momentum through entrainment, particularly if the ambient is moving. As the cloud comes close to a neutrally buoyant position, it may have a horizontal velocity close to that of the ambient. At the same time, the concentration of the waste material would be greatly reduced while the vorticity, having been dissipated through the action of ambient stratification and turbulence would become insignificant. At this point the further motion and deformation of the cloud is still governed mostly by its momentum, buoyancy and ambient density stratification. The momentum tends to overshoot the convective element beyond the neutrally buoyant position, while the buoyancy force tends to bring the convective element back to the neutrally buoyant position. The combination of these two forces tends to make the cloud oscillate vertically. While the gross vertical motion of the cloud is largely suppressed, the cloud tends to collapse vertically and spread out horizontally seeking a hydrostatic equilibrium with the ambient fluid due to the density stratification in the latter. The conservation equations used in the convective descent phase still hold. However, as the cloud is collapsing more dimensions are needed to describe the phenomenon fully. If the cross section of the cloud is assumed to retain an ellipsoidal shape, it could be characterized by its major and minor axes b and a.

Neglecting vorticity, the conservation equations read:

Conservation of Mass

$$\frac{dV}{dt} = E\rho_a - \sum_i \sum_j S_{ij}\rho_{si} \qquad (3.3.11)$$

Conservation of Momentum

$$\frac{d\vec{M}}{dt} = F\vec{j} - \vec{D} + E\rho_a \vec{U}_a - \sum_i \sum_j S_{ij}\, \rho_{si} \vec{U} \qquad (3.3.12)$$

Conservation of Buoyancy

$$\frac{dB}{dt} = E\Delta_f - \sum_i \sum_j S_{ij}\, \Delta_{si} \qquad (3.3.13)$$

Conservation of Particles

$$\frac{dP_{ij}}{dt} = -S_{ij} \qquad (3.3.14)$$

where $V = \rho \frac{4}{3}\pi a b^2$

total mass inside the cloud

$$E = 2\pi\left(b^2 + \frac{a^2 b}{\sqrt{b^2 - a^2}} \log\left(\frac{\sqrt{b^2 - a^2} + a}{a}\right)\right)\left(\alpha\left|\vec{U} - \vec{U}_a\right| + \alpha_c \frac{db}{dt}\right)$$

entrainment in volume

$$S_{ij} = \pi b^2 \left|w_{sij}\right| C_{sij} (1 - \beta ij)$$

settled solid in volume

$$\vec{M} = C_M \rho \frac{4}{3}\pi a b^2 \vec{U}$$

momentum

$$F = \frac{4}{3}\pi a b^2 g(\rho - \rho_a)$$

buoyancy force

$$D_x = \frac{1}{2}\rho_a C_{D_3} \pi ab \left|\vec{U} - \vec{U}_a\right| (u - u_a)$$

drag force in x-direction

$$D_y = \frac{1}{2}\rho_a C_{D_4} \pi b^2 \left|\vec{U} - \vec{U}_a\right| v$$

drag force in y-direction

$$D_z = \frac{1}{2}\rho_a C_{D_3} \pi ab \left|\vec{U} - \vec{U}_a\right| (w - w_a)$$

drag force in z-direction

$$B = \frac{4}{3}\pi ab^2 \left(\rho_a(o) - \rho\right)$$

buoyancy

$$\Delta_f = \rho_a(o) - \rho_a$$

ambient density difference between that at the free surface and that at the position of the centroid of the cloud

$$\Delta_{si} = \rho_a(o) - \rho_{si}$$

density difference between the ambient at the free surface and solid particles

$$P_{ij} = \frac{4}{3}\pi ab^2 C_{sij}$$

solid volume in the cloud (3.3.15)

Most of the symbols are as defined before. α_c is introduced in the formulation to take into account the entrainment due to the collapse. The above equations cannot be solved unless pertinent information on the cloud is further introduced as follows.

In studying the collapse of the cloud, it will first be assumed that the cloud always retains an ellipsoidal shape characterized by its major and minor axes b and a. Choosing coordinate axes with origin fixed on the centroid of the cloud, the shape of the cloud may be represented by

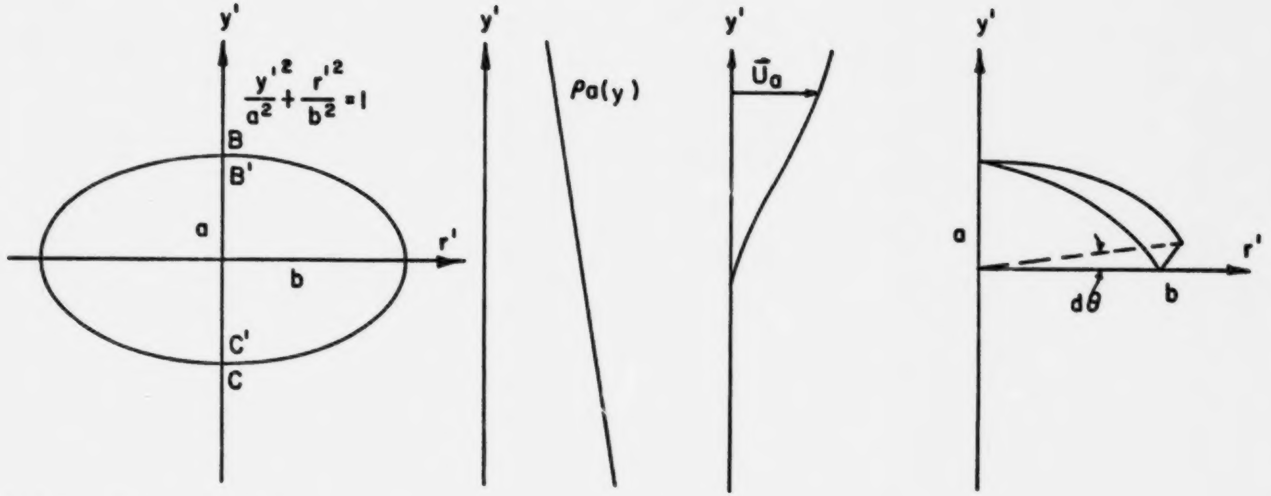
$$\frac{y'^2}{a^2} + \frac{r'^2}{b^2} = 1 \qquad (3.3.16)$$

where a and b are functions of time. In this formulation, the cloud is assumed to be symmetrical. It should be noted that in practice a symmetrical cloud can only obtain if there is no relative velocity between the cloud and the ambient fluid. Following the convective descent, the velocity difference between the cloud and the ambient is expected to be very small, and its influence on the shape may be assumed insignificant.

The ambient density distribution is

$$\rho_a(y) = (\rho + \Delta\rho)\Big(1 - \varepsilon(y)y'\Big) \qquad (3.3.17)$$

where ρ is the average density inside the cloud, $\Delta\rho$ is the density difference between the cloud and the ambient at $y' = 0$. (Note that $\Delta\rho$ can be positive or negative.) $\varepsilon(y)$ is the density gradient at $y' = 0$. Note that ρ, $\Delta\rho$ and $\varepsilon(y)$ are continuously changing as the cloud moves in an arbitrary density stratified ambient. The cloud and ambient condition are shown in Figures 3.3.2a and 3.3.2b.



(a) Configuration of the cloud (b) Ambient conditions (c) Slice segment

Figure 3.3.2 Definition sketch

As the vertical motion of the cloud slows down, the entrained ambient fluid might also make the density inside stratified. It is therefore further assumed that the density distribution inside the cloud is

$$\rho^*(y', r', t) = \rho\left(1 - \frac{\gamma a_o}{a} \epsilon(y) y'\right) \tag{3.3.18}$$

where $0 \leq \gamma \leq 1$ is a distribution constant to be determined from actual density distribution inside the region. If the density distribution inside the region is the same as the environment, i.e., $\gamma = 1$, there will be no spreading. Otherwise, $\gamma < 1$, and the cloud will collapse to seek a hydrostatic equilibrium.

The quantity $\gamma \frac{a_o}{a}$ represents a much simplified approximation to the ratio of the density gradients inside and outside the cloud. This should be further examined experimentally in the future and the term $\gamma \frac{a_o}{a}$ possibly modified.

Since it is assumed that the cloud is always symmetric, the collapse of the cloud can be determined by studying a slice of a segment as shown in Figure 3.3.2c. Taking this slice as a free body it is seen that there are two categories of forces on the slice: a) the driving force arising from the difference in the density structure, and b) the resistive forces consisting of i) the local inertia force of the segment, ii) the form drag of the collapsing segment and iii) the skin friction of the collapsing region.

In computing the driving force, one is referred to Figure 3.3.2. The pressures at B and B', C and C' should be equal respectively. Assuming hydrostatic pressures, the pressure distribution in the ambient can be calculated. The pressure inside depends on $\Delta\rho$, the acceleration of the convective element and the parameter γ. In the present study, $\Delta\rho$ is always very small and the acceleration effects are generally averaged out as the cloud oscillates about its neutrally buoyant position, thus the pressure distribution inside the cloud is approximately hydrostatic. Then the horizontal pressure force acting on the slice is

$$F_D = \frac{\rho_a \pi \left(1 - \frac{\gamma a_o}{a}\right) \epsilon g a^3 b}{16} d\theta \tag{3.3.19}$$

where $d\theta$ is the angle of the segment at $y' = 0$.

In computing the resistive forces, it is assumed that the horizontal velocities of elements inside the slice are related to the distance r' from the centroid of the cloud, and the velocity of horizontal deformation is characterized by the velocity of the centroid of the slice segment which is linearly related to the major axis of the ellipsoid b.

In collapsing, the horizontal spread and entrainment occur simultaneously, and the velocity of the centroid of the slice can be divided into two parts; one due to entrainment and the other due to collapse. Entrainment adds mass to the slice segment and it may entrain momentum into the cloud if the ambient is moving; however, the entrained momentum is already assumed to contribute to the momentum of the cloud as a whole as shown in Equation (3.3.12) and the cloud retains a symmetric shape. So when entrainment is considered for the slice, although the centroid of the slice is moving, there is no dynamics involved in this velocity. Hence, we will designate two velocities v_1 and v_2 representing the velocity of the segment tip for collapse and entrainment respectively and

$$\frac{db}{dt} = v_1 + v_2 \tag{3.3.20}$$

Then the local horizontal inertia force is

$$I = \frac{d}{dt}\left(\rho \frac{\pi a b^2}{16} v_1\right) d\theta \tag{3.3.21}$$

The form and skin friction drags are

$$D_d = C_{drag}\,\rho_a \frac{ab}{4} \left| v_1 \right| v_1 \, d\theta \qquad (3.3.22)$$

$$F_f = C_{frictn}\,\rho_a \frac{b^2}{2a} v_1 \, d\theta \qquad (3.3.23)$$

where C_{drag} and C_{frictn} are numerical coefficients similar to that of the drag coefficient for a wedge and the kinematic viscosity of the fluid. The equation of motion in the horizontal direction for the slice is

$$I = F_D - D_d - F_f \qquad (3.3.24)$$

In Equation (3.3.20), the tip velocity is related to the velocity induced by entrainment v_2. However, in Equation (3.3.11), only the gross mass entrained into the cloud is considered. In the dynamic collapse phase, as the cloud collapses horizontally, it can be visualized that the entrained mass is mostly added to the tip of the cloud, hence equation (3.3.11) can be rewritten to specify how entrainment adds to the growth of b. That is

$$v_2 = \frac{E\rho_a - \sum_i \sum_j S_{ij}\,\rho_{si}}{\rho \, \frac{8}{3}\pi \, ab} \qquad (3.3.25)$$

Equation (3.3.25) states that in each step of entrainment the contribution of the entrainment to the growth of b is approximated by holding ρ and a constant.

Equations (3.3.11-25) constitute a set of equations readily solvable for the pertinent parameters a, b, $\vec{U}$, ρ and C_{sij} given a set of initial conditions that can be obtained from the solution of the convective descent phase.

3.3.3 Bottom Encounter

If the density stratification is not strong enough the waste cloud is ultimately going to hit the bottom and spread out at the bed while the settling of the solid particles continues. In this Section, a mathematical model will be developed for this possibility. The model used will be essentially an extension of the model for dynamic collapse.

When the cloud hits the ocean bottom, it is assumed that it keeps the shape of half an ellipsoid as shown in the upper half of Figure 3.3.2a. The equation for its shape is

$$\frac{y'^2}{a^2} + \frac{r'^2}{b^2} = 1 \qquad (3.3.26)$$

Again the cloud is assumed to remain symmetric although velocity difference between the cloud, the bed and the ambient is allowed. The ambient density distribution is

$$\rho_a(y) = (\rho + \Delta\rho)(1 - \varepsilon(y)y') \qquad (3.3.27)$$

where $\varepsilon(y)$ is the density gradient at the centroid of the half ellipsoid.

The density inside the cloud is assumed to be

$$\rho^*(y', r', t) = \rho\left(1 - \frac{\gamma a_o}{a}\varepsilon(y)y'\right) \qquad (3.3.28)$$

The situation is very close to that of dynamic collapse; the vertical motion is suppressed by the bottom, and the cloud is mainly undergoing only horizontal spreading. The equations used in dynamic collapse can essentially be used again. However, two more forces, the reaction force and friction force at the bed, must be incorporated into the equations. The equations are

Conservation of Mass

$$\frac{dV}{dt} = E\rho_a - \sum_i \sum_j S_{ij}\rho_{si} \tag{3.3.29}$$

Conservation of Momentum

$$\frac{d\vec{M}}{dt} = F\vec{j} - \vec{D} + E\rho_a\vec{U}_a - \sum_i \sum_j S_{ij}\rho_{si}\vec{U} - \vec{F}_F \tag{3.3.30}$$

Conservation of Buoyancy

$$\frac{dB}{dt} = E\rho_f - \sum_i \sum_j S_{ij}\rho_{si} \tag{3.3.31}$$

Conservation of Particles

$$\frac{dP_{ij}}{dt} = -S_{ij} \tag{3.3.32}$$

Dynamic Equation for a Slice of a Half Ellipsoid

$$I = F_d - D_d - F_f - F_{bf} \tag{3.3.33}$$

The Tip Velocity of the Segment

$$\frac{db}{dt} = v_1 + v_2 \tag{3.3.34}$$

Contribution of Entrainment to the Growth of b

$$v_2 = \frac{E\rho_a - \sum_i \sum_j S_{ij}\rho_{si}}{\frac{4}{3}\pi ab} \tag{3.3.35}$$

where $V = \rho \frac{2}{3} \pi a b^2$

total mass in the cloud

$$E = \pi \left(b^2 + \frac{a^2 b}{\sqrt{b^2 - a^2}} \log \left(\frac{\sqrt{b^2 - a^2} + a}{a} \right) \right) \left(\alpha \left| \vec{U} - \vec{U}_a \right| + \alpha_c \frac{db}{dt} \right)$$

entrainment in volume

$$S_{ij} = \pi b^2 \left| w_{sij} \right| C_{sij} (1 - \varepsilon_{ij})$$

settled particles in volume

$$\vec{M} = C_M \rho \frac{2}{3} \pi a b^2 \vec{U}$$

momentum

$$F = \frac{2}{3} \pi a b^2 g (\rho - \rho_a)$$

buoyancy force

$$D_x = \frac{1}{4} \rho_a C_{D_3} \pi a b \left| \vec{U} - \vec{U}_a \right| (u - u_a)$$

drag force in x-direction

$$D_y = 0$$

drag force in y-direction

$$D_z = \frac{1}{4}\rho_a C_{D_3} \pi ab \left|\vec{U}-\vec{U}_a\right| (w-w_a)$$

drag force in z-direction

$$\psi = \sqrt{u^2+w^2}$$

resultant horizontal velocity

$$F_{Fx} = F_b \text{Frictn}\, u/\psi$$

friction force in x-direction

$$F_{Fy} = -F_b = -\frac{2}{3}\pi ab^2 g(\rho-\rho_a) + \frac{d}{dt}\left[C_M \rho \frac{2}{3}\pi ab^2 v\right]$$

$$+ \pi b^2 \sum_i \sum_j |w_{sij}| \Delta_{si} C_{sij}(1-\beta_{ij})v$$

reaction force at bed

$$F_{Fz} = F_b F_{rictn}\, w/\psi$$

friction force in z-direction

$$B = \frac{2}{3}\pi ab^2(\rho_a(o)-\rho)$$

buoyancy

$$\Delta f = \rho_a(o) - \rho_a$$

ambient density difference between that at the free surface and that at the position of the cloud centroid

$$\Delta_{si} = \rho_a(o) - \rho_{si}$$

density difference between the ambient at the free surface and the solid particles

$$P_{ij} = \frac{2}{3}\pi a b^2 C_{sij}$$

solid volume in the cloud

$$I = \frac{d}{dt}\left(\rho \frac{\pi a b^2}{16} v_1\right) d\theta$$

inertial force of a slice segment of a quadrant ellipsoidal cloud

$$F_d = \frac{\rho_a \pi \left(1 - \frac{a_o}{a}\right)}{16} \epsilon g a^3 b d\theta$$

driving force of the slice segment

$$D_d = C_{drag} \rho_a \frac{ab}{4} |v_1| v_1 d\theta$$

form drag of the slice segment

$$F_f = C_{frictn} \rho_a \frac{b^2}{2a} v_1 d\theta$$

skin friction of the slice segment

$$F_{bf} = F_b F_{rictn} F_1 d\theta / 2\pi \qquad (3.3.36)$$

friction force at the bed

In addition to the Equations (3.3.29-35), one more equation is needed for closure. That is

$$v = 0.75 \frac{a v_1}{b} \qquad (3.3.37)$$

where v is the vertical velocity of the centroid of a half ellipsoid.

Equation (3.3.37) is obtained by assuming zero entrainment, and the vertical deformation is readily obtained from horizontal deformation by continuity. Note that in computing the friction forces at the bed, reaction force times the friction coefficients F_1 and F_{rictn} is used.

Now Equations (3.3.29-37) are readily solvable given initial conditions that can be either obtained from the end of convective descent or from dynamic collapse. The solution and the links between these three phases will be deferred to Section 3.7.

3.4 Barge Operation 2: Jet Discharge

A large number of barges discharge the waste material through nozzles at the bottom of the barge, either by gravity or by pumping, while the barge is cruising at a certain speed. Near the nozzle, the flow phenomenon is that of a sinking jet in a cross current. The jet entrains ambient fluid and momentum while also experiencing a drag force from the ambient due to the pressure difference between the upstream and downstream faces of the jet. As a result, the jet grows in size and bends over in the direction of the ambient current. The waste material is diluted through entrainment of the ambient fluid and solid particles settle out of the jet as the situation allows. As the jet goes further downstream, it becomes less active and the influence from the ambient density gradient becomes dominant, and the jet fluid will spread out horizontally seeking a neutrally buoyant position.

The mixing phenomenon in buoyant jets and plumes has been studied by numerous investigators. Morton, Taylor and Turner (1956) applied an integral method to the problem of a buoyant plume discharged from a point source into a linearly stratified ambient fluid. Brooks and Koh (1965) analyzed the two dimensional buoyant jet problem with application to the design of submerged ocean outfall diffusers. Fan (1967) examined the case of a buoyant jet discharging at an arbitrary angle into a linearly density stratified quiescent ambient. Fan also analyzed the case of a buoyant jet in a uniform cross current. In the latter case, the ambient is not density stratified. In treating the problem of a buoyant jet in a uniform cross current, Fan assumed an entrainment mechanism based upon the vector difference between the characteristic jet velocity and the ambient velocity and the existence of a gross drag term for the unbalanced pressure field on the sides of the jet flow. Fan found that the drag coefficient needed to be varied from 0.1 up to 1.7 in fitting the predictions from his mathematical model to experimental data. Abraham (1970) examined the same problem of a buoyant jet in a uniform cross current employing a similar approach except that the entrainment was assumed to consist of two parts: one due to the momentum jet and the other due to the buoyant plume. Abraham was successful in fitting all of Fan's data with the mathematical model with a single value for the drag coefficient.

Singamsetti (1966) investigated the diffusion of sediment in a submerged jet. The jet containing sand was injecting vertically downward into a quiescent ambient. Singamsetti found that the concentration distribution in the jet is approximately normal and the mass diffusion is slightly faster than the diffusion of momentum.

In this investigation, Abraham and Fan's approach will be extended to study a sinking jet containing sediments in a density stratified non-uniform two dimensional cross stream for the flow pattern near the nozzle. As the jet goes further downstream, since mass and momentum of the ambient fluid are continuously entrained into the jet, it will move more or less at the velocity of the ambient, and the ambient density gradient effects will become dominant so that horizontal spreading similar to that treated in Section 3.3.2 for Barge Operation 1 will occur. Collapse of a two dimensional wake in a density stratified still ambient has been studied experimentally by Wu (1965) and analytically by Koh (1967) assuming no entrainment. In the analysis of dynamic collapse of the jet detailed in the following, Koh's basic approach extended to incorporate entrainment and cross current will be used.

3.4.1 Jet Convection

In this section, equations for a sinking jet in a stratified cross current will be formulated. Figure 3.4.1 shows a round jet discharging at a velocity into a cross current. It is assumed that the jet cross section remains circular. Top-hat velocity, density and concentration of waste material distribution are also assumed. Then the pertinent parameters for the jet are b, U, ρ and C_{sij} which are the radius, velocity, density and concentration of waste material respectively. The ambient density stratification is designated $\rho_a(y)$ and the cross current $U_a(y)$.

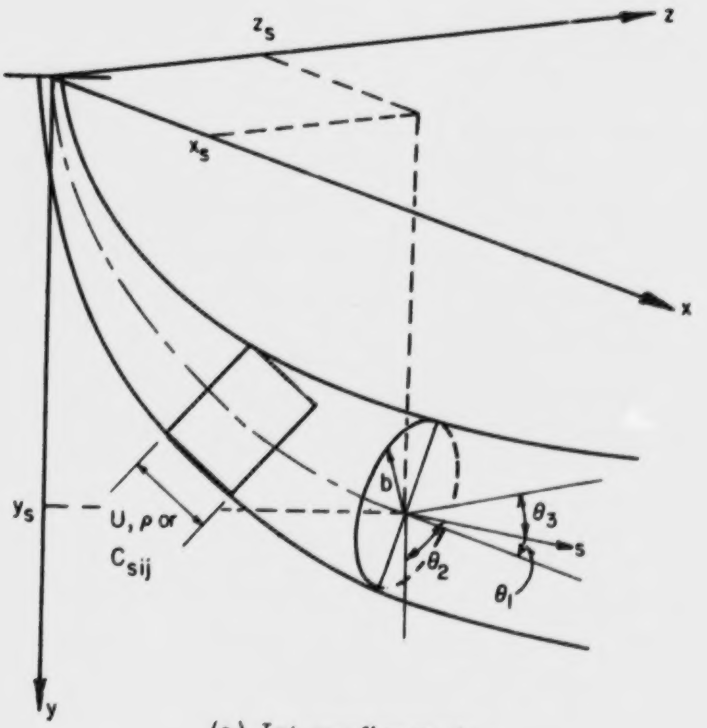
As shown in Figure 3.4.1, the jet can flow in any direction depending on its initial momentum and ambient current. In the figure, s is in the direction of the jet trajectory: θ_1, θ_2 and θ_3 are the angles between s and the x, y and z axes; δ_1 and δ_3 are the directions of the resultant ambient current at position s with respect to the x and z axes respectively; and γ is the angle between s and the resultant ambient current.

Physically, the flow is very similar to that in a momentum jet close to the nozzle. However, as the jet bends over towards the direction of the ambient current, the rise or fall of the plume is more like a two dimensional thermal. In this study, it is assumed, following Abraham (1970), that the entrainment mechanism depends on the local mean flow and consists of two parts as follows.

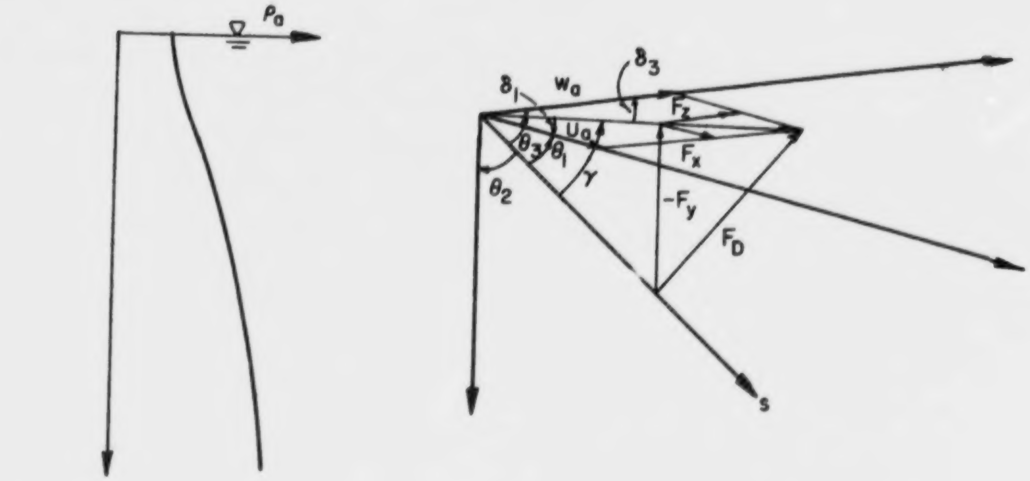
$$E_m = 2\pi b\alpha_1(U - U_a\cos\gamma) \qquad (3.4.1)$$

$$E_T = 2\pi b\alpha_2 U_a \sin\gamma \qquad (3.4.2)$$

Equation (3.4.1) states that the entrainment due to a momentum jet is proportional to the perimeter of the jet and the velocity difference



(a) Jet configuration



(b) Ambient density profile (c) Ambient velocity and drag forces

Figure 3.4.1 Definition sketch

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between the jet and the ambient in the direction of the jet travel. Equation (3.4.2) states that the entrainment due to a two-dimensional thermal is proportional to the perimeter of the jet and the velocity of the thermal. Note that Equation (3.4.2) is formulated by visualizing that the plume is essentially moving with the ambient velocity with a rising or descending velocity $U_a \sin\gamma$. In order to adequately take into account these two types of entrainment mechanisms, it is further assumed that the entrainment E is given by

$$E = E_m + E_T \sin\theta_2 \qquad (3.4.3)$$

Thus, the total entrainment is equal to the sum of the entrainment by momentum jet and the entrainment by a two-dimensional thermal modified by $\sin\theta_2$. $\sin\theta_2$ is arbitrarily chosen to diminish the thermal type of entrainment when the jet is close to vertical.

In the presence of a cross current, a force arises due to the unbalanced pressure field at the upstream and downstream faces of the jet. A gross drag force will be introduced and assumed to be perpendicular to the trajectory of the jet. The force is

$$F_D = C_D \frac{\rho_a (U_a \sin\gamma)^2}{2} 2b \qquad (3.4.4)$$

where C_D is the drag coefficient. The drag force components in x, y and z directions can be shown to be

$$F_{Dx} = \frac{-\cos\gamma \cos\theta_1 + \cos\delta_1}{\sin\gamma} F_D$$

$$F_{Dy} = \frac{-\cos\gamma \cos\theta_2}{\sin\gamma} F_D$$

$$F_{Dz} = \frac{-\cos\gamma \cos\theta_3 + \cos\delta_3}{\sin\gamma} F_D \qquad (3.4.4a)$$

The settling of solid particles from a jet is a most complicated phenomenon. The solid particles in the jet tend to settle out by gravity, however, they are also kept in the main stream by the turbulence in the jet. In the formulation of the settling, a settling coefficient β_{ij} will be introduced just as in Section 3.3.1. Then the term for settling of the solid becomes

$$S_{ij} = 2b \left| w_{sij} \right| C_{sij} (1 - \beta_{ij}) \qquad (3.4.5)$$

Based on the mechanisms of entrainment, drag and settling represented by Equations (3.4.1-5), the conservation equations become

Conservation of Mass

$$\frac{dV}{ds} = E\rho_a - \sum_i \sum_j S_{ij} \rho_{si} \qquad (3.4.6)$$

Conservation of Momentum

$$\frac{d\vec{M}}{ds} = F\vec{j} + E\rho_a \vec{U}_a - \sum_i \sum_j S_{ij} \rho_{si} \vec{U} - \vec{F}_D \qquad (3.4.7)$$

Conservation of Buoyancy

$$\frac{dB}{ds} = E\Delta_f - \sum_i \sum_j S_{ij} \Delta_{si} \qquad (3.4.8)$$

Conservation of Particles

$$\frac{dP_{ij}}{ds} = -S_{ij} \qquad (3.4.9)$$

where

$V = \pi b^2 \rho U$

flux of mass

$$\vec{M} = \pi b^2 \rho U \vec{U}$$

flux of momentum

$$F = \pi b^2 g(\rho - \rho_a)$$

buoyancy force per unit length

$$\Delta f = \rho_a(o) - \rho_a$$

density difference between free surface and position s

$$B = (\rho_a(o) - \rho)\pi b^2 U$$

flux of buoyancy

$$\Delta_{si} = \rho_a(o) - \rho_{si}$$

density difference between ambient free surface and solid particle

$$P_{ij} = \pi b^2 U C_{sij}$$

flux of solid particles (3.4.10)

Together with the geometric relationship

$$\cos^2\theta_1 + \cos^2\theta_2 + \cos^2\theta_3 = 1 \tag{3.4.11}$$

Equations (3.4.6-9) and Equation (3.4.11) constitute seven simultaneous ordinary differential equations for seven unknowns.

The equations can be solved with the initial conditions

$$U(o) = U_o, \quad b(o) = b_o, \quad \rho(o) = \rho_o, \quad C_{sij}(o) = C_{sijo}$$

$$\theta_1(o) = \theta_{1o}, \quad \theta_2(o) = \theta_{2o}, \quad \theta_3(o) = \theta_{3o} \tag{3.4.12}$$

The trajectory of the jet center line can be obtained through the following equations

$$\frac{dx}{ds} = \cos\theta_1$$

$$\frac{dy}{ds} = \cos\theta_2$$

$$\frac{dz}{ds} = \cos\theta_3 \tag{3.4.13}$$

Note that the formulation above is slightly different from that of Fan and Abraham. In particular, top-hat distributions are assumed for density deficiency, velocity and solid concentrations. However, since the integral approach integrates the distribution over the jet cross section, there is no essential difference in the resulting equations except for some modifications on the coefficients which are normally obtained through experiments.

3.4.2 Dynamic Collapse

When the jet plume is far downstream from the nozzle, it no longer behaves like a jet. Similar to the dynamic collapse phase of Barge Operation 1, the jet-plume tends to collapse vertically and spread out horizontally seeking a hydrostatic equilibrium in the ambient density gradient. In this section, a mathematical formulation is derived accounting for both the convection and the collapse of the waste material plume similar to that in Section 3.3.2.

Far downstream from the nozzle, the jet is expected to be moving approximately with the same velocity as the ambient, and the plume would be more like a two-dimensional thermal rather than a jet. In analogy with the arguments presented in Section 3.3.2, the cross section of the two-dimensional thermal will be assumed to have the shape of an ellipse.

$$\frac{y'^2}{a^2} + \frac{x'^2}{b^2} = 1 \qquad (3.4.14)$$

where x' and y' are coordinates with the origin fixed on the centroid of the thermal, a and b are minor and major axes of the ellipse and are functions of time. Again, the ambient density distribution is

$$\rho_a(y) = (\rho + \Delta\rho)(1 - \varepsilon(y)\, y') \qquad (3.3.15)$$

and the density distribution inside the cloud is

$$\rho^*(y', x', t) = \rho\left(1 - \frac{\gamma a_o}{a} \varepsilon(y)\, y'\right) \qquad (3.3.16)$$

The configuration of the two-dimensional thermal is shown in Figure 3.4.2.

By considering a two-dimensional thermal with a length L, the conservation equations are:

Conservation of Mass

$$\frac{dV}{dt} = E \rho_a - \sum_i \sum_j S_{ij} \rho_{si} \qquad (3.4.17)$$

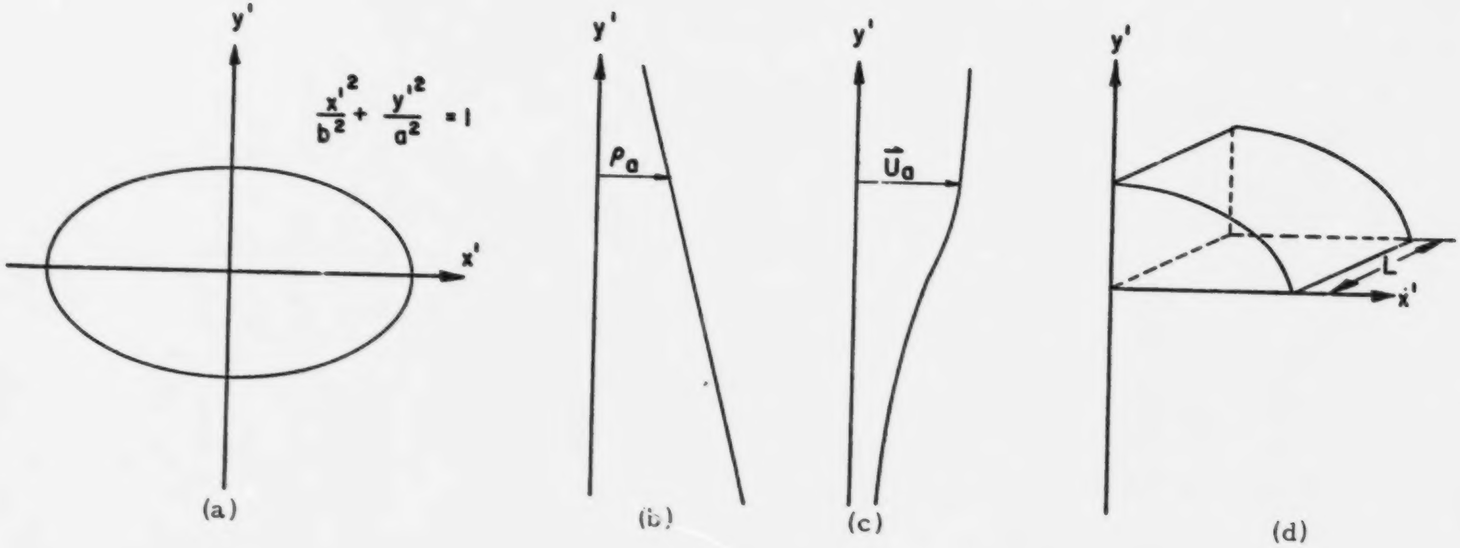


Figure 3.4.2 Definition sketch

Conservation of Momentum

$$\frac{d\vec{M}}{dt} = \vec{F}_j - \vec{D} + E \rho_a \vec{U}_a - \sum_i \sum_j S_{ij} \rho_{si} \vec{U} \qquad (3.4.18)$$

Conservation of Buoyancy

$$\frac{dB}{dt} = E \Delta f - \sum_i \sum_j S_{ij} \Delta_{si} \qquad (3.4.19)$$

Conservation of Particles

$$\frac{dP_{ij}}{dt} = - S_{ij} \qquad (3.4.20)$$

where

$V = \rho \pi abL$

total mass in the buoyant element

$E = 2\pi \frac{\sqrt{a^2 + b^2}}{2} L(\alpha_3 |\vec{U} - \vec{U}_a| + \alpha_4 \frac{db}{dt})$

total entrainment in volume

$S_{ij} = 2bL |w_{sij}| C_{sij}(1 - \beta_{ij})$

settled solids in volume

$\vec{M} = C_M \rho \pi abL\vec{U}$

momentum

$F = \pi abL(\rho - \rho_a)g$

buoyancy force

$$D_x = \frac{1}{2} C_{D_3} 2a\, L \sin\phi\, \rho_a \left|\vec{U} - \vec{U}_a\right| (u - u_a)$$

drag force in x-direction

$$D_y = \frac{1}{2} C_{D_4} 2b\, L \rho_a \left|\vec{U} - \vec{U}_a\right| v$$

drag force in y-direction

$$D_z = \frac{1}{2} C_{D_3} 2a\, L \cos\phi\, \rho_a \left|\vec{U} - \vec{U}_a\right| (w - w_a)$$

drag force in z-direction

$$B = \pi ab\, L (\rho_a(o) - \rho)$$

buoyancy

$$\Delta f = \rho_a(o) - \rho_a$$

ambient density difference between that at the free surface and that at the position of the centroid of the buoyant element

$$\Delta_{si} = \rho_a(o) - \rho_{si}$$

density difference between the ambient at the free surface and the solid particles

$$P_{ij} = \pi ab\, L C_{sij} \qquad (3.4.21)$$

solid volume in the buoyant element

In the above equations, α_3 and α_4 are entrainment coefficients for convection and collapse respectively. C_{D3} is drag coefficient for a two-dimensional streamlined wedge, C_{D4} is drag coefficient for a two-dimensional plate, and φ is the angle between L and the x-axis.

The equation for the dynamic collapse of a quadrant of the elliptical cylinder with length L is (in analogy with Section 3.3.2)

$$I = F_D - D_D - F_f \qquad (3.4.22)$$

where

$$I = \frac{d}{dt}\left(\frac{ab}{3} L \varepsilon v_1\right)$$

inertia

$$F_D = g \rho_a \frac{1}{6} L \left(1 - \frac{a_o}{a} \gamma\right) \varepsilon a^3$$

driving force

$$D_D = C_{drag} \frac{\rho_a a}{2} L v_2 |v_2|$$

form drag

$$F_f = C_{fric} \frac{b}{a} L v_2 \qquad (3.4.23)$$

skin friction

The tip velocity of the segment is given by

$$\frac{db}{dt} = v_1 + v_3 \qquad (3.4.24)$$

In the Equations (3.4.22) and (3.4.24) v_1 is the tip velocity due to collapse and v_2 is the combination of the tip velocity due to dynamic collapse and that due to the stretching of L.

$$v_2 = v_1 - \frac{b}{L}\frac{dL}{dt} \qquad (3.4.25)$$

v_3 is the contribution to tip velocity from entrainment by instantaneously holding ρ, a and L constant.

$$v_3 = \frac{E\rho_a - \sum_i \sum_j S_{ij}\rho_{si}}{\rho\pi a L} \qquad (3.4.26)$$

In the present formulation, at the end of jet convection, the two-dimensional thermal model immediately takes over the convection of the waste material plume. At that moment, the horizontal velocity of the element may be different from that of the ambient velocity. As the buoyant element is moving downstream, it will be slowed down or speeded up by entrainment of ambient momentum and by the drag force applied on it. However, the supply of waste material is continuous from the jet, hence, the two-dimensional element L should be able to be either stretched or squeezed in order that the trajectory of one convective element be capable of representing the steady picture of a continuous plume. In the estimate of the stretching of L, it is assumed that

$$\frac{L}{\sqrt{u^2 + w^2}} = \text{constant} \qquad (3.4.27)$$

The contribution from the stretching of L to the tip motion is obtained by assuming that the minor axis a is kept constant, and that no entrainment occurs at that moment.

The trajectory of the two-dimensional buoyant element is furnished by

$$\frac{dx}{dt} = u$$

$$\frac{dy}{dt} = v$$

$$\frac{dz}{dt} = w \qquad (3.4.28)$$

The initial conditions for dynamic collapse are from the information at the end of jet convection.

3.4.3 Bottom Encounter

Just as in the case of Barge Operation 1, the waste material plume can reach the ocean bottom and spread out there if the ambient density stratification is not strong enough to arrest the vertical descent of the plume somewhere above the bottom. A mathematical model which is an extension of the model presented in Section 3.4.2 will be developed in this section for this special situation.

At bottom encounter, the cross section of the plume is assumed to have a half ellipical shape as shown in the upper half of Figure (3.4.2a)

$$\frac{y'^2}{a^2} + \frac{x'^2}{b^2} = 1 \qquad (3.4.29)$$

The ambient density distribution is

$$\rho_a(y) = (\rho + \Delta\rho)(1 - \varepsilon(y)y') \qquad (3.4.30)$$

The density distribution inside the plume is

$$\rho^*(y', x', t) = \rho\left(1 - \frac{\gamma a_0}{a}\,\varepsilon(y)y'\right) \qquad (3.4.31)$$

The ocean bed is assumed to be horizontal. The plume is allowed to move as an entity with respect to the ambient fluid and the ocean bed, while it collapses vertically and spreads out horizontally. By following essentially the same arguments as presented in Sections 3.3.2, 3.3.3 and 3.4.2, the equations become

Conservation of Mass

$$\frac{dV}{dt} = E\rho_a - \sum_i \sum_j S_{ij}\,\rho_{si} \qquad (3.4.32)$$

Conservation of Momentum

$$\frac{d\vec{M}}{dt} = F\vec{j} - \vec{D} + E\rho_a\vec{u}_a - \sum_i \sum_j S_{ij}\rho_{si}\vec{U} - \vec{F}_F \qquad (3.4.33)$$

Conservation of Buoyancy

$$\frac{dB}{dt} = E\Delta_f - \sum_i \sum_j S_{ij}\Delta_{si} \qquad (3.4.34)$$

Conservation of Particles

$$\frac{dP_{ij}}{dt} = -S_{ij} \qquad (3.4.35)$$

where

$$V = \frac{1}{2}\rho\pi ab\,L$$

total mass in the buoyant element

$$E = \pi\sqrt{\frac{a^2+b^2}{2}}\,L(\alpha_3|\vec{u}-\vec{u}_a| + \alpha_4\frac{db}{dt})$$

entrainment in volume

$$S_{ij} = 2bL\,|w_{sij}|C_{sij}(1-\beta_{ij})$$

settled solid in volume

$$\vec{M} = \frac{1}{2}C_M\rho\pi ab\,L\vec{U}$$

momentum

$$F = \frac{1}{2}\pi ab\,L(\rho-\rho_a)g$$

buoyancy force

$F_{Fx} \quad = \quad F_b F_{rictn}(u-u_b)/\psi$

bottom friction force in x-direction

$F_{Fy} \quad = \quad -F_b \quad = \quad -F+\frac{d}{dt}(\frac{1}{2}C_M \rho\pi ab\, Lv) + \sum_i \sum_j S_{ij} v \rho_{si}$

reaction force at the bed

$F_{Fz} \quad = \quad F_b F_{rictn}(w-w_b)/\psi$

bottom friction force in z-direction

$\psi \quad = \quad \sqrt{(u-u_b)^2 + (w-w_b)^2}$

resultant velocity difference between the plume element and the bed

$D_x \quad = \frac{1}{2} C_{D3} a\, L \sin\theta \rho_a \,|\vec{U} - \vec{U}_a|(u-u_a)$

drag force in x-direction

$D_y \quad = \frac{1}{2} C_{D4} 2bL \rho_a \,|\vec{U} - \vec{U}_a|\, v$

drag force in y-direction

$D_z \quad = \frac{1}{2} C_{D3} aL\cos\theta \rho_a \,|\vec{U} - \vec{U}_a|(w-w_a)$

drag force in z-direction

$B \quad = \frac{1}{2} \pi ab\, L(\rho_a(o) - \rho)$

buoyancy

$\Delta_f \quad = \rho_a(o) - \rho_a$

ambient density difference beyween that at the free surface and that at the position of the buoyant element

$\Delta_{si} \quad = \rho_a(o) - \rho_{si}$

density difference between the ambient at the free surface and the solid particles

$P_{ij} \quad = \frac{1}{2}\pi ab\, L\, C_{sij}$

solid volume in the buoyant element (3.4.36)

In the above equations, u_b and w_b are velocities of the bed with respect to a coordinate fixed on the moving barge.

The equation for the dynamic collapse of a quadrant of the elliptical cylinder is

$$I = F_D - D_D - F_f - F_{bf} \qquad (3.4.37)$$

where

$I \quad = \frac{d}{dt}(\frac{ab}{3} L \rho v_1)$

inertial force

$F_D \quad = g \rho_a \frac{1}{6} L(1 - \frac{a_o}{a}\gamma)\, \epsilon a^3$

driving force

$$D_D = C_{drag} \frac{\rho_a a}{2} L v_2 |v_2|$$

form drag

$$F_f = C_{fric} \frac{b}{a} L v_2$$

skin friction

$$F_{bf} = F_b F_{rictn} F_1$$

friction at the bed (3.4.38)

The tip velocity of the segment is

$$\frac{db}{dt} = v_1 + v_3 \qquad (3.4.39)$$

In the above equations, v_1 is the tip velocity due to collapse, v_2 is tip velocity due to the combination of collapse and the stretching of element length, and v_3 is the tip velocity due to entrainment (see Section (3.4.2)). And the vertical velocity of the centroid is obtained by continuity assuming no entrainment and settling at an instant.

$$v = \frac{4}{3\pi} \frac{a}{b} v_1 \qquad (3.4.40)$$

The trajectory is again furnished by

$$\frac{dx}{dt} = u$$

$$\frac{dy}{dt} = v \qquad (3.2.41)$$

$$\frac{dz}{dt} = w$$

The initial conditions for this phase can be obtained from jet convection or dynamic collapse.

3.5 Barge Operation 3 - Discharge into Barge Wake

In the disposal of highly harmful waste material, it may be desirable to discharge it into the wake of a moving barge to achieve high initial mixing. After the initial mixing, the waste material plume is again expected to undergo a convective descent phase due to the density difference between the mixed waste material and the ambient fluid, and a dynamic collapse phase when the plume reaches a neutrally buoyant position.

The initial mixing process in the wake of a moving barge is essentially a mass transfer process in separated flow. The flow field in the wake of a moving barge is complicated by flow separation from the stern, wave generation, turbulence developed in the shear zone, and back flow following the separation. The phenomena of mass and heat transfer in separated flow has been investigated in the literature; for example, Richardson (1963) studied experimentally the heat and mass transfer in the wake of a cylinder. He found that shear and mass transfer in a separated region is proportional to the two thirds power of Reynolds number. Ruckenstein (1970) and Spalding (1967) developed some theoretical relationships between the mass transfer coefficient and physical parameters of the flow for two simple flow conditions: constant shear and linear shear. There is some confirmation between the studies by Richardson and Ruckenstein. Hanson and Richardson (1968) further investigated the flow field in the wake of a cylinder in great detail in an attempt to find a relationship between the flow field and heat or mass transfer. Elzy et al (1968) studied the heat transfer for a porous cylinder in a cross flow where the local heat transfer coefficient for different injection rate and turbulence intensity were obtained. Mass transfer in separated flow depends heavily on the pattern of the flow field. For the flow field in the wake, in spite of its being a classical problem, theoretical development has been mainly limited to the far field of the wake as presented by Swain (1929). Carmody (1964) and Chevray (1968) made extensive experimental and analytical studies on the near wake of a disk and an ellipsoid respectively. The results were found to depend on the form of the body. Kuo and Baldwin (1969) examined the formation of wakes behind elliptical plates. Strong dependence of the far field on the results of the near field was found. Naudascher (1967, 1968) in a study of the general characteristics of jet and wake flows, developed a general self-preservation hypothesis. The lateral distribution of various mean-flow and turbulence characteristics obtained from measurements in axisymmetric jets and wakes were shown to confirm his concept of self-preservation.

Ketchum and Ford (1952) have analyzed the discharge of fluid waste material into the wake of a moving barge where mixing was observed to be instantaneous in the vertical direction. The transverse dispersion coefficients were calculated from prototype experimental data. Abraham et al (1970) investigated the mixing of acid into a propeller stream of a moving ship for the case where the mixed stream density is very close to the ambient density so that the mixed stream stays close to the free surface. The dilution in the wake was measured.

In the following, an initial mixing phase will be formulated based on the assumption that the material is perfectly mixed into the main stream as calculated by Naudascher's semi-empirical analysis. After the initial mixing a two dimensional thermal approach will be used for the convective descent phase. For the subsequent dynamic collapse phase, the analysis presented in Sections 3.4.2 and 3.4.3 will be used.

3.5.1 Initial Mixing in the Near Wake of a Barge

The mixing phenomenon in the near wake of a barge is so complicated that a complete analytical solution to the problem is impossible. Here a simple gross approach will be used. This is desirable from a practical point of view since at least some insight into the significance of disposal into the barge wake can be obtained from the present analysis.

It is first assumed that the flow rate of the waste material is comparatively small so that it is completely mixed into the wake by the turbulence without altering the wake flow pattern. Secondly, the effect of waves is disregarded so that the flow pattern can be approximated from Naudascher's analysis of jet and wake flows.

In generalizing the distribution and development of mean-flow and turbulence characteristics in jet and wake flows, Naudascher reduced the flow pattern in the near field of disk and ellipsoid wakes (Figure 3.5.1) to a similarity form by introducing a length scale ℓ_Q, which is a function of measured velocity distributions. The velocity distributions are approximated by

$$\frac{\bar{U}_d}{U_d} = e^{-\eta^2} \qquad (3.5.1)$$

as shown in Figures 3.5.2 and 3.5.3. In Equation (3.5.1), U_d is the local velocity deficit, $\bar{U}_d$ is the maximum velocity deficit and

$$\eta = \frac{y}{\ell_Q}$$

where y is the radial distance. The length scale ℓ_Q was found to vary for different flow conditions as shown in Figure (3.5.4). It can be approximated by

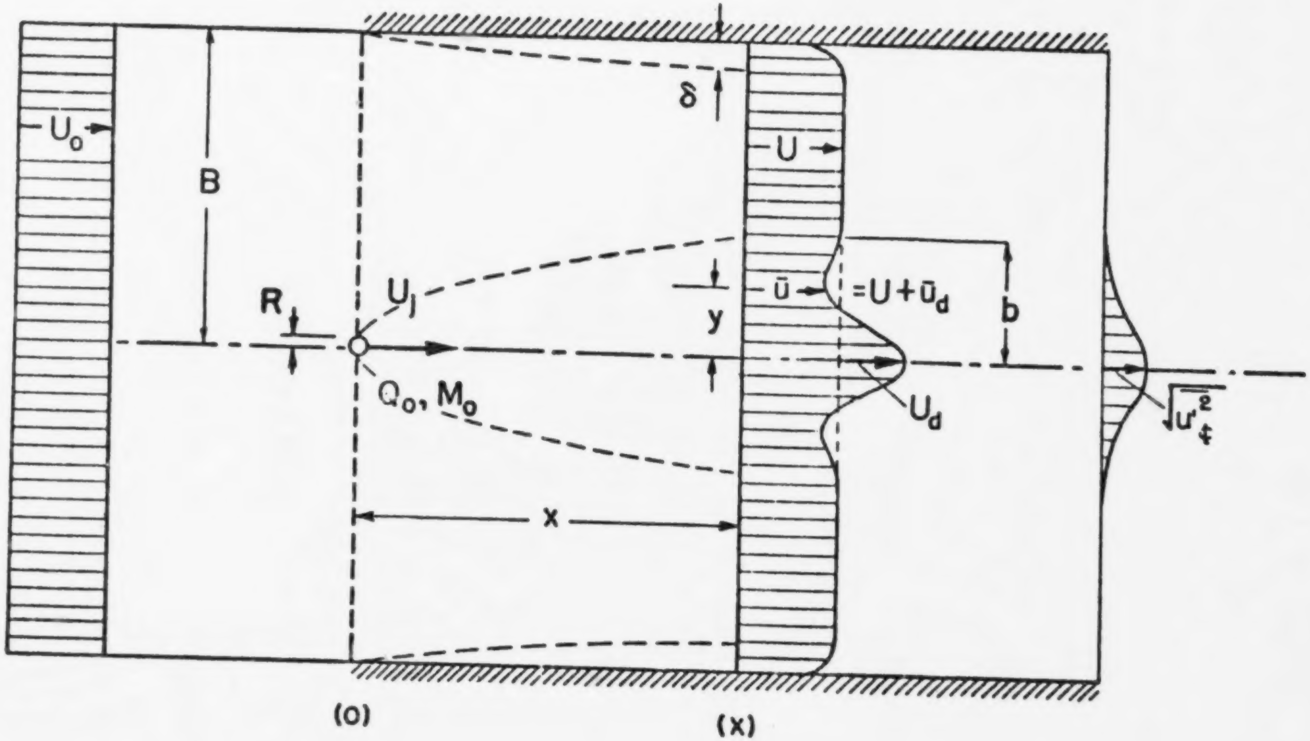


Figure 3.5.1 Definition sketch (After Naudascher 1968)

$$\frac{\ell_Q}{R} = C_1\left(\frac{y}{R}\right)^{1/3} \tag{3.5.2}$$

where C_1 is a constant for each group of data and approximately varies from 0.15 up to 1.0 for the two extreme cases of a blunt disk and a streamlined body of revolution. R is a characteristic length of the body which can be chosen as the geometric mean of the barge depth and half width in the present analysis.

By assuming that similarity exists after a distance $x = C_2R$ downstream from the barge stern, the velocity distribution at that position becomes

$$\frac{\overline{U}_d}{U_d} = e - \left(\frac{y}{C_1C_2^{1/3}R}\right)^2 \tag{3.5.1a}$$

By referring to Figures 3.5.2 to 3.5.4, if we take $\eta = 2.0$ as the nominal boundary of the wake, then the radius of the wake is

$$Y = 2C_1C_2^{1/3}R \tag{3.5.3}$$

and the mean velocity is

$$\overline{U} = \frac{1}{4\pi}\int_0^2 U_d(1-e^{-\eta^2})\,2\pi\eta\,d\eta = 0.75\,U_d \tag{3.5.4}$$

at $x = C_2R$ where similarity of flow pattern begins.

If the waste material is assumed to mix uniformly into the wake within the nominal boundary, then the concentration can be estimated by

$$C_{sij} = \frac{Q_dC_{ijo}}{0.5\pi Y^2\overline{U}} \tag{3.5.5}$$

where Q_d is the discharge rate and C_{ijo} is the initial concentration of the solid particles. Note that the formulation in Equations (3.5.3, 3.5.5)

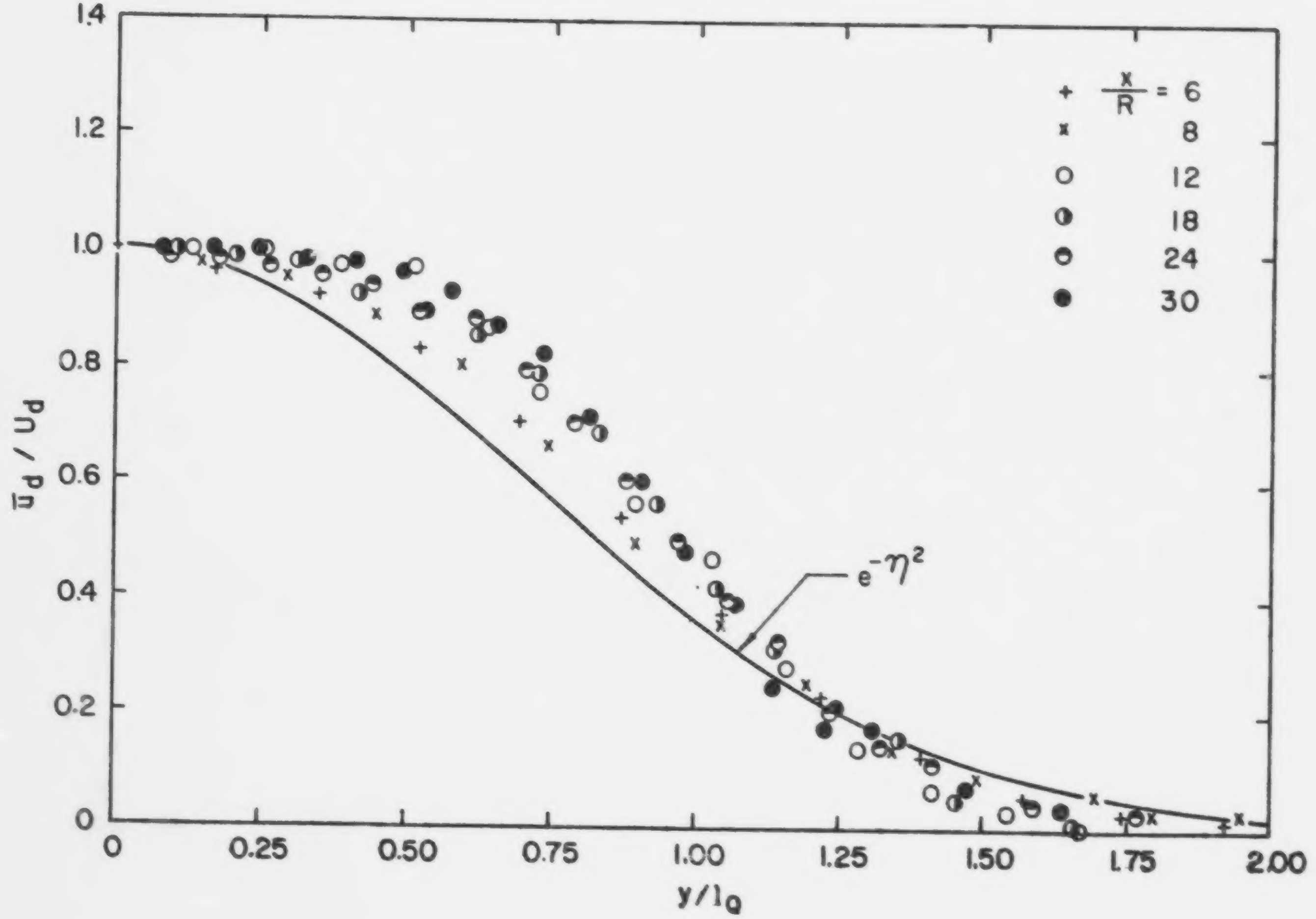


Figure 3.5.2 Radial variation of mean-velocity difference in the wake of a disk. (After Naudascher 1968) (Data by Carmody for $UR/\nu \simeq 35,000$; $m = -0.57$.)

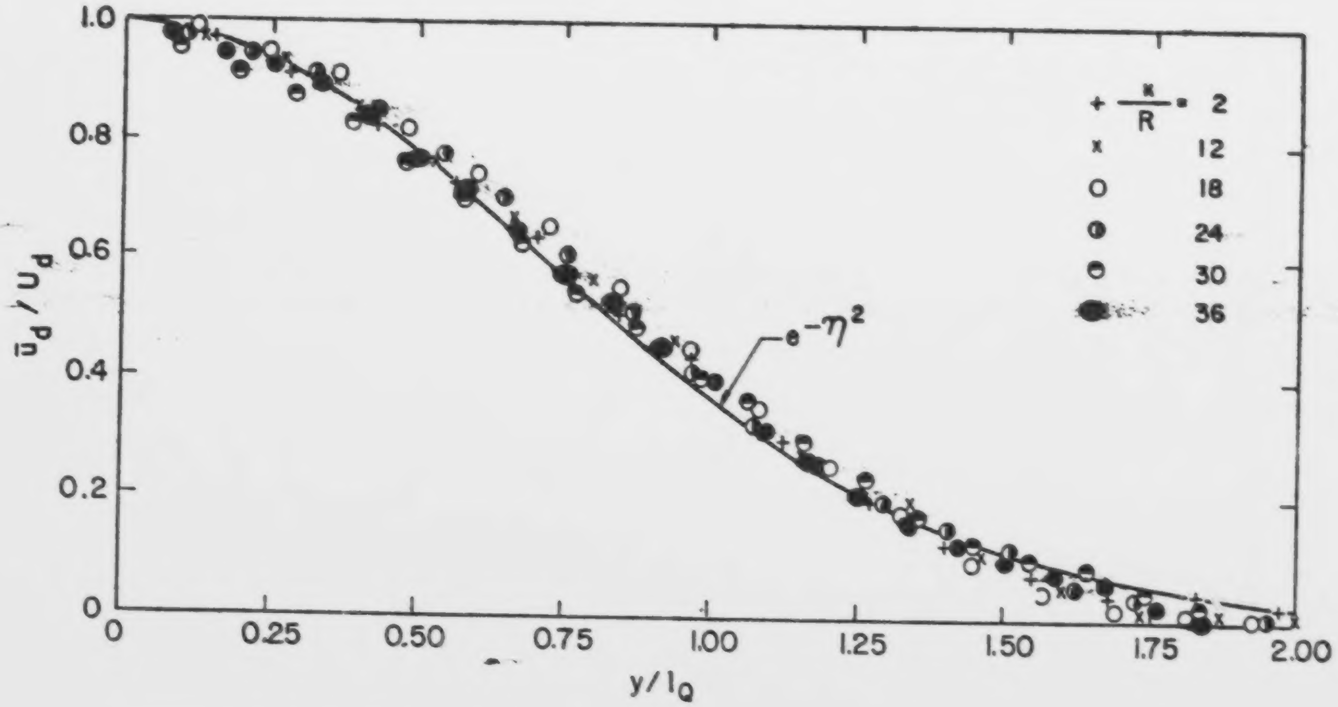


Figure 3.5.3 Radial variation of mean-velocity difference in the wake of a slender spheroid. (After Naudascher 1968) (Data by Chevray for $UR/\nu \simeq 1,375,000$; $m = -0.03$.)

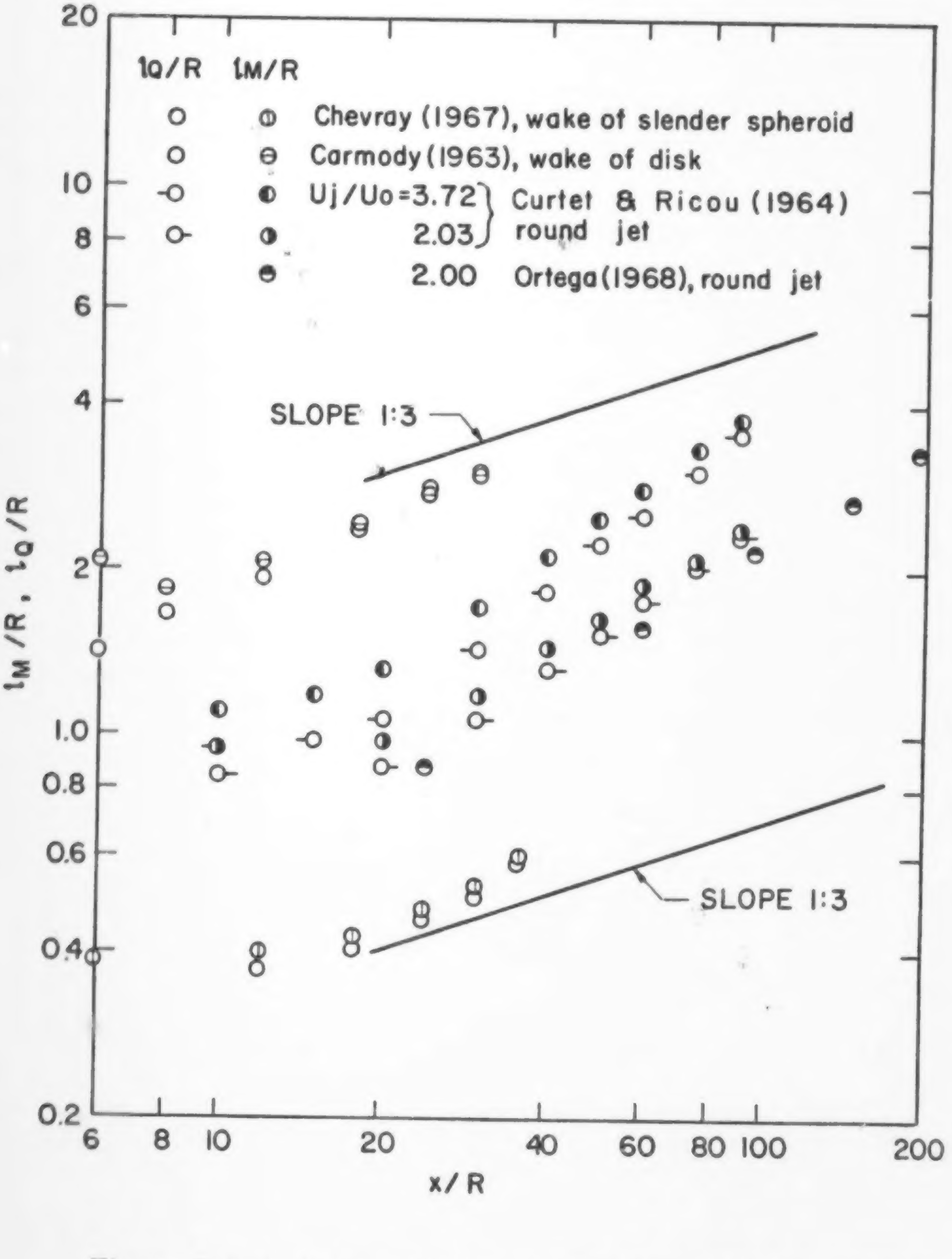


Figure 3.5.4 Axial variation of effective width for various jet and wake flows. (After Naudascher (1968))

is quite general and by properly choosing C_1 and C_2 the flow pattern of any barge wake can be approximated. The judgment as to the exact values of C_1 and C_2 should be based on further experimental information.

3.5.2 Convective Descent

In the initial mixing phase, it is tentatively assumed that because of the strong turbulent mixing in the near wake, the buoyancy effect is of secondary importance. However, after the initial mixing, as the turbulence subsides the buoyancy will make the half cylinder waste material plume descend vertically to seek a neutrally buoyant position while it is convected downstream by the ambient current.

In this convective descent phase, it is assumed that the plume retains a half cylindrical shape so that a two-dimensional thermal approach can be used. Then by considering a two-dimensional thermal with a length L, the conservation equations become

Conservation of Mass

$$\frac{dV}{dt} = E\rho_a - \sum_i \sum_j S_{ij}\rho_{si} \qquad (3.5.6)$$

Conservation of Momentum

$$\frac{d\overrightarrow{M}}{dt} = F\vec{j} - D + E\rho_a\vec{U}_a - \sum_i \sum_j S_{ij}\rho_{si}\vec{U} \qquad (3.5.7)$$

Conservation of Buoyancy

$$\frac{dB}{dt} = E\Delta f - \sum_i \sum_j S_{ij}\Delta_{si} \qquad (3.5.8)$$

Conservation of Particles

$$\frac{dP_{ij}}{dt} = -S_{ij} \qquad (3.5.9)$$

where

$V = \frac{1}{2}\pi b^2 L$

total mass in the buoyant element

$E = \pi b L \left(\alpha v + \alpha_1 \left((u-u_a)^2 + (w-w_a)^2\right)^{1/2}\right)$

total entrainment in volume

$S_{ij} = 2bL\,|w_{sij}|\,C_{sij}(1-\beta_{ij})$

settled solids in volume

$\vec{M} = \frac{1}{2}C_M\,\rho\pi b^2 L\vec{U}$

momentum

$F = \frac{1}{2}\pi b^2 L(\rho - \rho_a)g$

buoyancy force

$D_x = \frac{1}{2}C_{D_1} bL\sin\varphi\,\rho_a\,|\vec{U} - \vec{U}_a|\,(u-u_a)$

drag force in x-direction

$D_y = \frac{1}{2}C_{D_2} 2bL\,\rho_a\,|\vec{U} - \vec{U}_a|\,v$

drag force in y-direction

$D_z = \frac{1}{2}C_{D_1} bL\cos\varphi\,\rho_a\,|\vec{U} - \vec{U}_a|\,(w-w_a)$

drag force in z-direction

$B = \frac{1}{2}\pi b^2 L(\rho_a(o) - \rho)$

buoyancy

$\Delta f \quad = \rho_a(o) - \rho_a$

ambient density difference between that at the free surface and that at the position of the centroid of the buoyant element

$\Delta_{si} \quad = \rho_a(o) - \rho_{si}$

density difference between the ambient at the free surface and the solid particles

$P_{ij} \quad = \frac{1}{2}\pi b^2 LC_{sij}$

solid volume in the buoyant element (3.5.10)

In the above equations, α and α_1 are the entrainment coefficients for a two-dimensional thermal and a momentum jet respectively, C_{D_1} and C_{D_2} are the drag coefficients for a two-dimensional wedge and a two-dimensional cylinder respectively, ϕ is the angle L makes with the x-axis.

The element length and velocity relationship is assumed to be such that

$$\frac{L}{\sqrt{u^2 + w^2}} = \text{constant} \tag{3.5.11}$$

The contribution from stretching of L to the growth of b is obtained by assuming no entrainment or settling occurring at that moment. The Equations (3.5.6-11) are readily solvable given initial conditions from the initial mixing phase.

3.5.3 Subsequent Motions

Following the convective descent phase, the subsequent motions and dispersion of the waste plume is obtained by using the same model developed for the corresponding phases for jets (see Section 3.4).

3.6 Long Term Diffusion

In the long run, regardless of the exact method of disposal of the waste material from the barge, after the initial phases of convection and collapse the waste plume becomes dynamically passive subject only to turbulent diffusion, advection and settling of the solid particles.

Ocean diffusion has been studied by investigators from various disciplines including geophysicists, oceanographers and engineers. Previous studies of marine diffusion have not only determined quantitatively ocean transport characteristics as discussed in Section 3.2, but also established different methods of analyses. In general, most of the analysis starts from the concept of the conservation of material expressed as

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(D_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z \frac{\partial c}{\partial z}\right) \tag{3.6.1}$$

where c is the concentration of the diffusing substance, (u, v, w) are local instantaneous velocities in (x, y, z) directions, (D_x, D_y, D_z) are molecular diffusion coefficients in (x, y, z) directions. In turbulent flow, Equation (3.6.1) may be further simplified by resolving the instantaneous concentrations and velocities into the sum of time averaged and fluctuating components.

$$c = \bar{c} + c', \quad \vec{u} = \bar{\vec{u}} + \vec{u}'$$

where the overbar indicates the averaged value which is the result of averaging over a sufficiently long period to permit convergence of the averages of the primed quantities to zero. Making the appropriate substitution in Equation (3.6.1), and averaging the resulting equation over a sufficiently long period, introducing the definitions (3.2.1)

$$K_x = \frac{\overline{-u'c'}}{\frac{\partial \bar{c}}{\partial x}} + D_x, \quad K_y = \frac{\overline{-v'c'}}{\frac{\partial \bar{c}}{\partial y}} + D_y, \quad K_z = \frac{\overline{-w'c'}}{\frac{\partial \bar{c}}{\partial z}} + D_z$$

(3. 2. 1)

and dropping the overbars for simplicity gives

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(K_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial c}{\partial z}\right)$$

(3. 6. 2)

Most of the early investigations were confined to the study of horizontal diffusion only, employing simplified versions of Equation (3. 6. 2); current shear and vertical exchange were ignored, i. e., in Equation (3. 6. 2) K_y, v and w are taken to be zero. Horizontal diffusion has been investigated by stommel (1949), Joseph and Sender (1962), Okubo (1962), Carter and Okubo (1965), Snyder (1967) and others. These studies yielded information on the horizontal transport characteristics of the ocean, as was summarized in Section 3. 2. Perhaps the most significant result from these studies is the empirical 4/3 power law, (Equation (3. 2. 2)) for the horizontal diffusion coefficient.

A model neglecting the effects of vertical shear current and vertical diffusion is inadequate in describing the whole dispersion phenomenon in the ocean. The shear current tends to stretch out the distribution and shift the centroids of material distributions at different levels. Vertical diffusion tends to redistribute the material in the vertical direction. These effects result in greater dilution of the diffusing substance than a model which only considers horizontal diffusion.

The effect of current shear in ocean (or lake) diffusion problems have been studied by Okubo (1968), Okubo and Carter (1966), Bowden (1965), and Csanady (1963, 1966). These analyses were mostly aimed at the determination of apparent longitudinal diffusion coefficient. Recently, Koh and Fan (1968, 1969), studied the diffusion of the radioactive debris distribution subsequent to a deep underwater nuclear explosion. In this investigation, shear current and vertical diffusion were incorporated. For the horizontal diffusion, the empirical 4/3 power law were used. Jobson and Sayre (1970) examined the vertical transfer of fluid and sediment particles in open channel flow. From experimental data of the vertical distribution of the dispersant at sections downstream from a continuous source across the width of a channel, they evaluated the vertical transfer coefficient as function of depth. It was found that for fine sediment ($w_s = 0.035$ fps) the vertical transfer coefficient distribution is close to the momentum transfer coefficient obtained by assuming a logarithmic vertical velocity distribution. For coarse sediment ($w_s = 0.2$ fps), more diviation between the two coefficient distributions were observed. However, from the results of numerical simulation of the vertical transfer phenomenon, Jobson and Sayre concluded that the predicted concentration profiles were not very sensitive to the distribution of the vertical mass transfer coefficient.

Sayre (1968) investigated the longitundinal dispersion of silt in open channel flow. Vertical momentum transfer coefficient was used for the mass transfer coefficient. Comparison of the results with experimental data was found to be good.

The approach used by Bowden (1965), Okubo (1968), Sayre (1968) was the so called method of moments. The method begins by defining the moments of the concentration distributions across horizontal planes. Equation (3.5.2) is then transformed into a set of equations for these moments with t and y as the independent variables. The equations of moments are considerably simpler to solve, and the important characteristics of the diffusing substance can be determined from only the first few moments. The problem then is solved with no sacrifice of rigor but at the expense of some loss of detail. With its simplicity and capability of incorporating fairly realistic ambient conditions, the method of moments will be adopted in this investigation and presented in detail in the following sections.

3.6.1 Formulation of the Theoretical Model

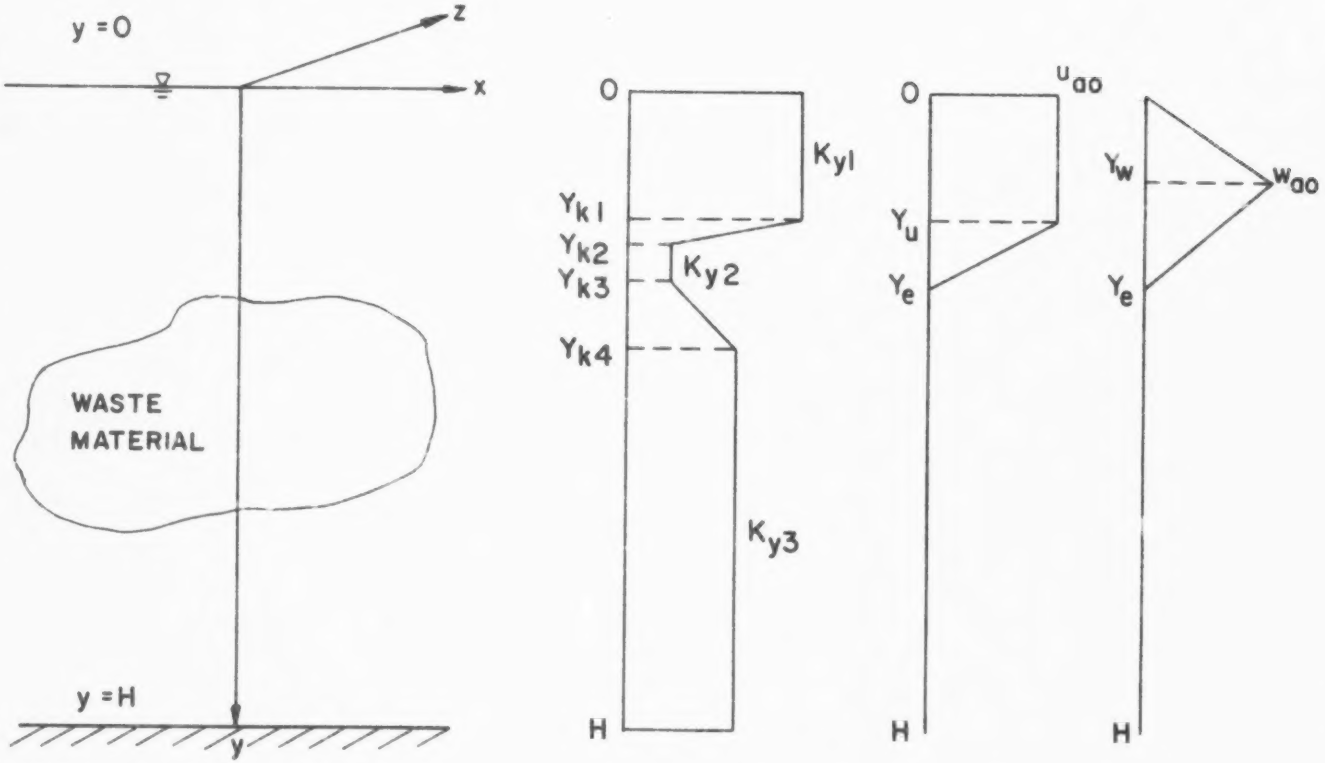
For solving the long term diffusion problem of waste material in the ocean environment, the method of moments will be used. Coordinate system, ambient conditions and basic equation will be given in Section 3.6.1.1, Derivation of equations will be presented in Section 3.6.1.2. Numerical solution of the equations and the computer program will be deferred to Section 3.7.

3.6.1.1 Flow Configuration and Basic Equation

The coordinate system is chosen to be as shown in Figure 3.6.1. x, z are horizontal coordinates, y is the vertical coordinate pointing downward from the free surface. The ambient current in the ocean are designated as (u_a, o, w_a) in (x, y, z) directions. Note that the mean v-component is neglected here, considering the effect of the stable density stratification in the ocean. The mean u_a and w_a components are taken to be independent of the x and z coordinates but may be functions of y and t. These are all assumed to be known functions. By considering a specific group of the waste material particles settling with fall velocity w_s while being convected and diffused by the ambient current and turbulence, the conservation of material equation is similar to Equation (3.6.2) except for one more term involving the fall velocity as follows.

$$\frac{\partial C}{\partial t} + u_a \frac{\partial C}{\partial x} + w_a \frac{\partial C}{\partial z} = \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) - \frac{\partial}{\partial y}\left(w_s C\right) \tag{3.6.3}$$

where C is the time averaged concentration of the waste material, u_a and w_a are ambient currents and w_s is the fall velocity. Note that Equation (3.6.3) is satisfied by both the liquid and the solid part of the waste matter depending on the value assigned to the fall velocity w_s.



(a) Coordinate System

K_y-profile

u_a-profile

w_a-profile

Figure 3.6.1 Coordinate System and Ambient Conditions for long term diffusion model

Corresponding to Equation (3.6.3), boundary conditions are needed for each of the waste material treated as follows.

i) For fluid $w_s = 0$

$$y = 0, H \qquad \frac{\partial C}{\partial y} = 0 \tag{3.6.4}$$

Equation (3.6.4) indicates that there is no diffusion of material through the boundaries, and the boundaries act as reflecting barriers to the diffusion material.

ii) For sinking particles w_s = positive

$$y = 0, \quad K_y \frac{\partial C}{\partial y} - w_s C = 0 \tag{3.6.5a}$$

$$y = H, \quad K_y \frac{\partial C}{\partial y} - (1 - \alpha_2) w_s C - \gamma_2 W_2 = 0 \tag{3.6.5b}$$

$$\frac{\partial W_2}{\partial t} - \alpha_2 w_s C + \gamma_2 W_2 = 0 \tag{3.6.5c}$$

iii) Floating particles; w_s = negative

$$y = 0, \quad K_y \frac{\partial C}{\partial y} - (1 - \alpha_1) w_s C + \gamma_1 W_1 = 0 \tag{3.6.6a}$$

$$\frac{\partial W_1}{\partial t} + u_{a1} \frac{\partial W_1}{\partial x} + w_{a1} \frac{\partial W_1}{\partial z} + \alpha_1 w_s C + \gamma_1 W_1$$
$$= \frac{\partial}{\partial x}\left(K_{xw} \frac{\partial W_1}{\partial x}\right) + \frac{\partial}{\partial z}\left(K_{zw} \frac{\partial W_1}{\partial z}\right) \tag{3.6.6b}$$

$$y = H, \quad K_y \frac{\partial C}{\partial y} - w_s C = 0 \qquad (3.6.6c)$$

In the above equations, α is a bed absorbency coefficient representing the probability that a particle of sediment coming into contact with the bed is deposited, W represents the amount of sediment stored per unit area of bed surface (or free surface), and γ is an entrainment rate coefficient, defined in such a way that $\gamma \Delta t$ is the probability that a typical particle resting on the bed is entrained during a short time interval of duration Δt. γW represents an average rate of entrainment. The subscripts 1 and 2 signifies the values at the free surface and at bed respectively.

As shown in Equations (3.6.5, 3.6.6), the boundary conditions for solid particles are fairly complicated. The settling of the sinking solid particles will be further discussed below. At the free surface the transport by fall velocity is balanced by diffusion as shown in Equation (3.6.5a). At the bed, a fictitious double layered bed is introduced; the first boundary is the boundary of the fluid and the second is the boundary where the solid particles can be stored. At the first boundary there are three mechanisms for transport, namely convection by fall velocity, diffusion by turbulence and entrainment by ambient flow. These are schematically presented in Figure 3.6.2 . As shown in Figure 3.6.2, $\alpha_2 w_s C$ represents the rate of deposition down to the second boundary, $(1-\alpha_2) w_s C$ is the rate of retention in the fluid, $K_y \frac{\partial C}{\partial y}$ is the rate of diffusion and $\gamma_2 W_2$ is the rate of entrainment of particles from the second boundary back into the fluid. Equation (3.6.5b) summarizes these mechanisms and indicates that the combined actions of diffusion, entrainment and settling contributes no net transport across the boundary. On the second boundary, whatever is settled there will increase the storage of waste material which in turn again is subjected to detrainment. Equation (3.5.5c) just expresses the conservation of waste material while allowing the waste material to be stored, Corresponding to Equation (3.6.3), boundary conditions are needed for each of the waste material treated as follows.

i) For fluid $w_s = 0$

$$y = 0, H \qquad \frac{\partial C}{\partial y} = 0 \tag{3.6.4}$$

Equation (3.6.4) indicates that there is no diffusion of material through the boundaries, and the boundaries act as reflecting barriers to the diffusion material.

ii) For sinking particles w_s = positive

$$y = 0, \quad K_y \frac{\partial C}{\partial y} - w_s C = 0 \tag{3.6.5a}$$

$$y = H, \quad K_y \frac{\partial C}{\partial y} - (1 - \alpha_2) w_s C - \gamma_2 W_2 = 0 \tag{3.6.5b}$$

$$\frac{\partial W_2}{\partial t} - \alpha_2 w_s C + \gamma_2 W_2 = 0 \tag{3.6.5c}$$

iii) Floating particles; w_s = negative

$$y = 0, \quad K_y \frac{\partial C}{\partial y} - (1 - \alpha_1) w_s C + \gamma_1 W_1 = 0 \tag{3.6.6a}$$

$$\frac{\partial W_1}{\partial t} + u_{a1} \frac{\partial W_1}{\partial x} + w_{a1} \frac{\partial W_1}{\partial z} + \alpha_1 w_s C + \gamma_1 W_1$$
$$= \frac{\partial}{\partial x}\left(K_{xw} \frac{\partial W_1}{\partial x}\right) + \frac{\partial}{\partial z}\left(K_{zw} \frac{\partial W_1}{\partial z}\right) \tag{3.6.6b}$$

$$y = H, \quad K_y \frac{\partial C}{\partial y} - w_s C = 0 \qquad (3.6.6c)$$

In the above equations, α is a bed absorbency coefficient representing the probability that a particle of sediment coming into contact with the bed is deposited, W represents the amount of sediment stored per unit area of bed surface (or free surface), and γ is an entrainment rate coefficient, defined in such a way that $\gamma \Delta t$ is the probability that a typical particle resting on the bed is entrained during a short time interval of duration Δt. γW represents an average rate of entrainment. The subscripts 1 and 2 signifies the values at the free surface and at bed respectively.

As shown in Equations (3.6.5, 3.6.6), the boundary conditions for solid particles are fairly complicated. The settling of the sinking solid particles will be further discussed below. At the free surface the transport by fall velocity is balanced by diffusion as shown in Equation (3.6.5a). At the bed, a fictitious double layered bed is introduced; the first boundary is the boundary of the fluid and the second is the boundary where the solid particles can be stored. At the first boundary there are three mechanisms for transport, namely convection by fall velocity, diffusion by turbulence and entrainment by ambient flow. These are schematically presented in Figure 3.6.2. As shown in Figure 3.6.2, $\alpha_2 w_s C$ represents the rate of deposition down to the second boundary, $(1 - \alpha_2) w_s C$ is the rate of retention in the fluid, $K_y \frac{\partial C}{\partial y}$ is the rate of diffusion and $\gamma_2 W_2$ is the rate of entrainment of particles from the second boundary back into the fluid. Equation (3.6.5b) summarizes these mechanisms and indicates that the combined actions of diffusion, entrainment and settling contributes no net transport across the boundary. On the second boundary, whatever is settled there will increase the storage of waste material which in turn again is subjected to detrainment. Equation (3.5.5c) just expresses the conservation of waste material while allowing the waste material to be stored,

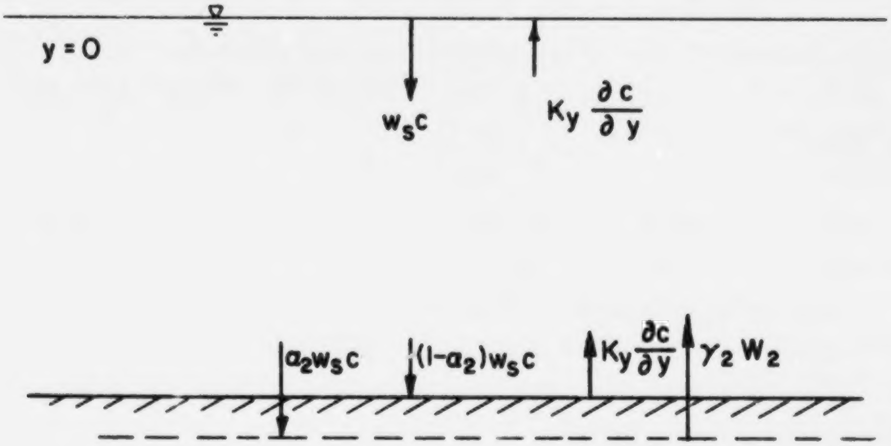

y = 0
$w_s c$
$K_y \frac{\partial c}{\partial y}$
$\alpha_2 w_s c$
$(1-\alpha_2) w_s c$
$K_y \frac{\partial c}{\partial y}$
$\gamma_2 W_2$

Figure 3.6.2 Schematic for boundary conditions for solids settling to the bed

and exchanged with those in the fluid. For the floating particles the same argument applies. However, after the solids have settled to the surface, it is also subjected to horizontal diffusion by turbulence and advection by ambient currents at the free surface and therefore these terms are added as shown in Equation (3.6.6b).

3.6.1.2 Method of Moments

Equation (3.6.3) with any one of the corresponding boundary conditions for fluid, sinking particles or floating particles can be solved given the initial conditions of the concentration distribution in the fluid and the deposition of the waste material on the bed or free surface. However, Equation (3.6.3) can have analytical solutions only in simple cases, and with its four independent variables x, y, z and t, a numerical solution of Equation (3.6.3) will require considerable storage and computer time. Also, as noted in Section 3.2, the values of the diffusion coefficients are often determined based upon the gross characteristics of the dispersant. It is believed to be more consistant in the analysis to ignore the detailed distributions but solve for only the gross characteristics of the dispersant as functions of time and depth.

Applying the technique of the moment method, as given previously by Saffman (1962), Smith (1965), Tydesley and Wallington (1965) Bowden (1965), and Sayre (1968), the moments of the concentration $C(x, y, z, t)$ and waste material deposition $W(x, y, z, t)$ across horizontal planes are defined as follows:

$$C_{k,\ell} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^k z^\ell C \, dx \, dz \tag{3.6.7}$$

$$M_{k,\ell} = \int_0^H C_{k,\ell} \, dy \tag{3.6.8}$$

$$W_{k,\ell} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^k z^\ell W \, dx\, dz \qquad (3.6.9)$$

These express respectively the k, ℓ'th moment of the horizontal distribution. Thus, for example taking $k = \ell = 0$, Equations (3.6.7-9) represents respectively: (1) The amount of dispersant contained in a lamina of unit thickness at a distance y below the free surface; (2) all the waste material in suspension; (3) the amount of dispersant on the bed or free surface. The sum of Equations (3.6.8) and (3.6.9) $M_{k,\ell} + W_{k,\ell}$, is the k, ℓ'th moment of the horizontal distribution of all the waste material.

Multiplication of each term in Equation (3.6.3) by $x^k z^\ell$ followed by integration over the horizontal plane yields the transformed equation,

$$\frac{\partial}{\partial t} C_{k,\ell} - k u_a C_{k-1,\ell} - \ell w_a C_{k,\ell-1}$$

$$= k(k-1) K_x C_{k-2,\ell} + \ell(\ell-1) K_z C_{k,\ell-2}$$

$$+ \frac{\partial}{\partial y}\left(K_y \frac{\partial C_{k,\ell}}{\partial y} - w_s C_{k,\ell}\right) \qquad (3.6.10)$$

The boundary conditions transform to

i) Fluid $w_s = 0$

$$y = 0, H \quad \frac{\partial C_{k,\ell}}{\partial y} = 0 \qquad (3.6.11)$$

ii) For sinking particles w_s = positive

$$y = 0, \quad K_y \frac{\partial C_{k\ell}}{\partial y} - w_s C_{k,\ell} = 0 \qquad (3.6.12a)$$

$$y = H, \quad K_y \frac{\partial C_{k\ell}}{\partial y} - (1-\alpha_2) w_s C_{k,\ell} - \gamma_2 W_{2k,\ell} = 0 \tag{3.6.12b}$$

$$\frac{\partial W_{2k,\ell}}{\partial t} - \alpha_2 w_s C_{k,\ell} + \gamma_2 W_{2k,\ell} = 0 \tag{3.6.12c}$$

iii) For floating particles; w_s = negative

$$y = 0, \quad K_y \frac{\partial C_{k\ell}}{\partial y} - (1 - \alpha_1) w_s C_{k,\ell} + \gamma_1 W_{1k,\ell} = 0 \tag{3.6.13a}$$

$$\begin{aligned} \frac{\partial}{\partial t} W_{1k,\ell} - k u_{a1} W_{1k-1,\ell} - \ell w_{a1} W_{1k,\ell-1} + \alpha_1 w_s C_{k,\ell} & \\ + \gamma_1 W_{1k,\ell} = k(k-1) K_{xw} C_{k-2,\ell} & \\ + \ell(\ell-1) K_{zw} C_{k,\ell-2} & \end{aligned} \tag{3.6.13b}$$

$$y = H, \quad K_y \frac{\partial C_{k,\ell}}{\partial y} - w_s C_{k,\ell} = 0 \tag{3.6.13c}$$

The initial distribution of deposited waste material and that in suspension can be transformed in the same manner.

It should be noted that the independent variables x and z have been eliminated in the moments. The solutions to the new set of equations are correspondingly simpler. The penalty for this is that the solutions give only the moments of the horizontal distribution of waste material rather than the distribution itself. Still, the behavior of the moments provides a sufficient basis for the description of the dispersion process. In principle, any desired degree of detail can be achieved by solving the equations for sufficiently high values of k and ℓ. In practice, the first three moments are usually all that are required.

Table 3.6 shows how the 0'th, first and second moments can be used to calculate statistical parameters which are useful for describing various aspects of the dispersion process. In the formulas the subscripts s and w denote respectively the suspended and deposited components of the waste material, and T denote the sum of both. The argument (y, t) indicates the value of the function at y and t. The argument (t) in conjunction with the subscript s indicates a depth integral for all the suspended material.

3.6.2 Diffusion Coefficients

From Equation (3.6.10), it is seen that the diffusion coefficients K_x, K_y and K_z are important to the dispersion process. Following the discussion of Section 3.2, the relationship between the horizontal diffusion coefficient and cloud size can be defined. However, the interrelationship between the vertical diffusion coefficient and the ambient condition is less well known. In this study the vertical diffusion coefficient will be assumed to be as given in Figure 3.6.1b; the K_y value is minimum at the thermocline, and maximum in the mixed layer.

For the horizontal diffusion coefficient, the 4/3 - power law in the ocean as discussed in Section 3.2.3 will be used. The relation is given by Equation (3.2.2)

TABLE 3.6

USE OF MOMENTS TO DESCRIBE DISPERSION

Moment	Desired Statistical Parameter	Formula
0	Volume under concentration curve	$V_s(y,t) = C_{00}$ $V_s(t) = M_0(t)$ $V_T(t) = M_0(t) + W_{00}(t)$ $=$ Total waste material
1	Mean displacement	$x_s(y,t) = C_{10}/C_{00}$ $z_s(y,t) = C_{01}/C_{00}$ $Y(t) = M_1/M_0$ $x_w(t) = W_{10}/W_{00}$ $z_w(t) = W_{01}/W_{00}$
2	Variance	$\sigma_{xs}^2 = C_{20}/C_{00} - x_s^2$ $\sigma_{zs}^2 = C_{02}/C_{00} - z_s^2$ $\sigma_{xzs}^2 = C_{11}/C_{00} - x_s z_s$ $\sigma_y^2 = M_2/M_0 - Y^2$ $\sigma_{xw}^2 = W_{20}/W_{00} - x_w^2$ $\sigma_{zw}^2 = W_{02}/W_{00} - x_w^2$ $\sigma_{xzw}^2 = W_{11}/W_{00} - x_w z_w$

$$K_x, K_z = A_L L^{4/3} \qquad (3.2.2)$$

where A_L is a constant called dissipation parameter, and L is the size of the diffusing patch.

The size of a pool of waste material L is defined to be 4 times the standard deviation σ of the distribution, i.e. $L = 4\sigma$. Equation (3.2.2) can be written also in terms of σ, i.e.

$$K_x, K_z = A\sigma^{4/3} \qquad (3.2.2a)$$

where $A = 6.34\ A_L$ is a dissipation parameter defined based upon the value of standard deviation or L/4.

Since σ_x and σ_z in general are not equal, and σ_{xz} may not be zero, there are several possibilities in adopting the horizontal diffusion law (3.2.2) for use in the present theoretical model. One way is to define K_x and K_z separately by their corresponding σ_x and σ_z values, i.e.

$$K_x = A\sigma_x^{4/3} \quad \text{and} \quad K_z = A\sigma_z^{4/3} \qquad (3.2.2b)$$

Another method is to define the horizontal diffusion coefficients based upon the geometric mean of the standard deviations along the principal axes, i.e.

$$K_x = K_z = A(\sigma_x^2\sigma_z^2 - \sigma_{xz}^2)^{1/3} \qquad (3.2.2c)$$

Equation (3.2.2b) is not entirely logical because the K_x and K_z values depend on the choice of the coordinate system. Solutions will change with a change of coordinate directions. Equation (3.2.2c) gives identical K_x and K_z values but the length scale chosen is invariant under coordinate transformations. Moreover, in the field determinations of the values of A_L or A, the length scale was often taken to be proportional to the square root of the patch area which directly corresponds to the quantity $(\sigma_x^2\sigma_z^2 - \sigma_{xz}^2)^{1/4}$.

The value of A in Equation (5.2.2c) based upon a choice $A_L = 0.00015$ feet$^{2/3}$/second is $A = 0.001$ feet$^{2/3}$/second. In the model the relation (3.2.2c) is chosen to represent the horizontal diffusion law for the waste material in suspension, in solution or on the free surface.

Note that the theoretical model can handle more complicated diffusion laws. e.g. when A is a function of y, the depth instead of being a constant.

3.6.3 Limitations of the Theoretical Model

The theorectical model formulated in the previous section can handle cases where the ambient velocities, u_a and w_a, and the diffusion coefficients, K_x, K_y and K_z, are functions of both time t and depth y. As described in Section 3.2.3, these environmental quantities in the ocean are, in fact, generally functions of t and y. Therefore the model is thought to be sufficiently general to describe adequately the long-term diffusion of waste material in the ocean. However, the model is subject to the limitation that these environmental characteristics are independent of the x, z coordinates or invariant over the horizontal planes. This limitation is minor especially in the open ocean. In the practical case, if the environmental condition is slowly varying in the horizontal planes, or the horizontal variation across the pool of waste material is small, the average condition within the pool of waste material can be used at each instant as a good approximation.

Also note that in the formulation, the waste material is assumed to be in an open sea bounded only by horizontal bottom from below. However, if the ambient is bounded horizontally, such as an inland lake or a bay, the assumptions should be modified. If there is ambient current, since the velocity at the boundary has to be zero, by continuity the vertical velocity cannot be zero everywhere. In such situations, care must be taken in the application of the present model. If the area of the bounded ambient is large, and the discharge site is far from the boundary present assumptions can still be valid. If the bounded ambient is small horizontally, then the convective descent and dynamic collapse phases are of most interest anyway.

3.7 Numerical Procedure and Computer Program

In the previous sections, sets of equations for different stages of mixing for different barge operations were formulated. These sets of equations do not yield closed form analytical solutions. Therefore, they will be solved numerically on a digital computer. In the following sections, the numerical procedures for the solution of these equations will be presented.

3.7.1 Numerical Procedure

In Sections 3.3, 3.4, and 3.5, the formulations presented for convective descent and dynamic collapse phases consisted of systems of ordinary non-linear differential equations which are readily solvable given a set of initial conditions. A standard fourth order Runge Kutta method is employed in the solution of these equations.

For long term diffusion, in solving the hyperbolic partial differential equations, Equation (3.6.10), the Crank-Nicolson method with a relaxation factor of 0.5 is used and this will be briefly presented in the following.

A grid system shown in Figure 3.7.1 is chosen for finite difference approximation. In the diagram, i signifies the vertical grid points, j indicates the time steps and $\Delta y(i)$ is the distance between y_i and y_{i+1}. For the unsteady term, a forward difference is used.

$$\frac{\partial C_{k,\ell}}{\partial t} = \frac{C_{k,\ell}(i,j+1) - C_{k,\ell}(i,j)}{\Delta t} \qquad (3.7.1)$$

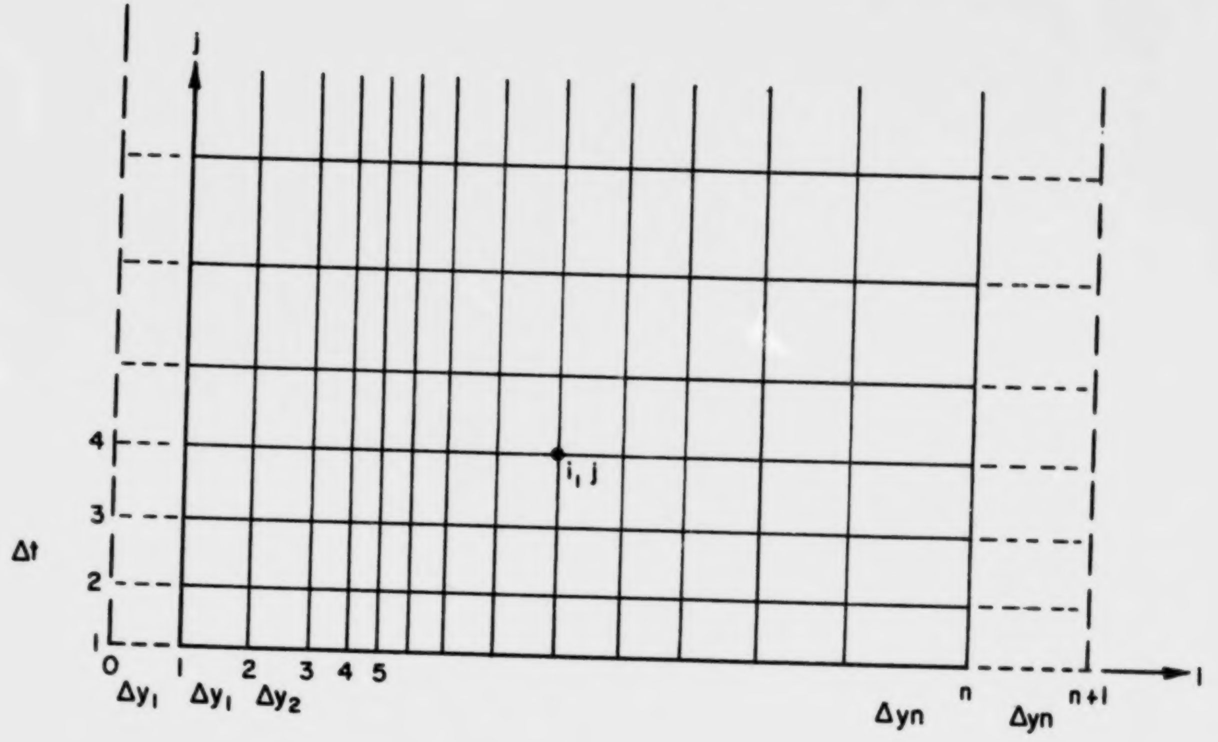


Figure 3.7.1 Grid System for Long Term Diffusion

The diffusion term is approximated by a central difference averaged over times j and j+1.

$$\frac{\partial}{\partial y}\left(K_y\frac{\partial C_{k,\ell}}{\partial y}\right) = \frac{K_y(i)[C_{k,\ell}(i+1,j+1) - C(i,j+1)]}{\Delta y(i)[\Delta y(i) + \Delta y(i-1)]}$$

$$- \frac{K_y(i-1)[C_{k,\ell}(i,j+1) - C(i-1,j+1)]}{\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]}$$

$$+ \frac{K_y(i)[C_{k,\ell}(i+1,j) - C_{k,\ell}(i,j)]}{\Delta y(i)[\Delta y(i) + \Delta y(i-1)]}$$

$$- \frac{K_y(i-1)[C_{k,\ell}(i,j) - C(i-1,j)]}{\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]} \qquad (3.7.2)$$

For the advective term involving the fall velocity, a backward difference is taken for a positive fall velocity and a forward difference for a negative fall velocity. The finite difference is also averaged over times j and j+1.

$$w_s\frac{\partial C_{k,\ell}}{\partial y} = 0.5w_s\frac{C_{k,\ell}(i+k_1,j+1) - C_{k,\ell}(i-k_2,j+1)}{[k_1\Delta y(i) + k_2\Delta y(i-1)]}$$

$$+ 0.5w_s\frac{C_{k,\ell}(i+k_1,j) - C_{k,\ell}(i-k_2,j)}{[k_1\Delta y(i) + k_2\Delta y(i-1)]} \qquad (3.7.3)$$

where

$$k_1 = \begin{cases} 0 \\ 1 \end{cases} \text{and } k_2 = \begin{cases} 1 \\ 0 \end{cases} \text{ if } w_s \begin{cases} >0 \\ <0 \end{cases}$$

At the boundaries, the diffusion term is approximated by a central difference using fictitious grid points beyond the real boundaries. Thus

$$\text{at } y=0 \qquad \frac{\partial C_{k,\ell}}{\partial y} = \frac{C_{k,\ell}(2,j) - C_{k,\ell}(0,j)}{2\Delta y(1)}$$

$$\text{and} \qquad \text{at } y=H \qquad \frac{\partial C_{k,\ell}}{\partial y} = \frac{C_{k,\ell}(n+1,j) - C_{k,\ell}(0,j)}{2\Delta y(n)} \tag{3.7.4}$$

Substituting Eqs. (3.7.1-4) into Eq. (3.6.10) and the boundary conditions yields a system of simultaneous difference equations as follows.

$w_s>0$, particles in suspension:

$$\begin{aligned}
i=1 \quad & -\left[\frac{1}{\Delta t} + \frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)} + \frac{w_s}{\Delta y(1)} + \frac{k_2 w_s^2}{(k_1+k_2)K_y(1)}\right]C_{k,\ell}(1,j+1) \\
& +\left(\frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)}\right)C_{k,\ell}(2,j+1) \\
= \quad & -0.5(ku_a(1)(C_{k-1,\ell}(1,j) + C_{k-1,\ell}(1,j+1)) + \ell w_a(1)(C_{k,\ell-1}(1,j) \\
& + C_{k,\ell-1}(1,j+1)) + k(k-1)K_x(1,j)(C_{k-2,\ell}(1,j) + C_{k-2,\ell}(1,j+1)) \\
& + \ell(\ell-1)K_z(1,j)(C_{k,\ell-2}(1,j) + C_{k,\ell-2}(1,j+1))) - \left[\left(\frac{1}{\Delta t} - \frac{K_y(1)}{\Delta y(1)^2}\right.\right. \\
& \left. - \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)} - \frac{w_s}{\Delta y(1)} - \frac{k_2 w_s^2}{(k_1+k_2)K_y(1)}\right)C_{k,\ell}(1,j) \\
& \left. + \left(\frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)}\right) C_{k,\ell}(2,j)\right]
\end{aligned} \tag{3.7.5}$$

$i = 2$ to $n-1$

$$
\begin{aligned}
&\left[\frac{K_y(i-1)}{\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]} + \frac{0.5 w_s k_2}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right] C_{k,\ell}(i-1, j+1) \\
&- \left[\frac{1}{\Delta t} + \frac{K_y(i)\Delta y(i-1) + K_y(i-1)\Delta y(i)}{\Delta y(i)\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]} + \frac{0.5 w_s (k_2 - k_1)}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right] C_{k,\ell}(i, j+1) \\
&+ \left[\frac{K_y(i)}{\Delta y(i)[\Delta y(i) + \Delta y(i-1)]} - \frac{0.5 w_s k_1}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right] C_{k,\ell}(i+1, j+1) \\
&= -0.5(k\, u_a(i)(C_{k-1,\ell}(i,j) + C_{k-1,\ell}(i,j+1)) + \ell w_a(i)(C_{k\ \ell-1}(i,j) \\
&+ C_{k,\ell-1}(i,j+1)) + k(k-1)K_x(i,j)(C_{k-2,\ell}(i,j) \\
&+ C_{k-2,\ell}(i,j+1)) + \ell(\ell-1)K_z(i,j)(C_{k,\ell-2}(i,j) + C_{k,\ell-2}(i,j+1))) \\
&- \Bigg(\left(\frac{K_y(i-1)}{\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]} + \frac{0.5 w_s k_2}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right) C_{k,\ell}(i-1, j) \\
&+ \left(\frac{1}{\Delta t} - \frac{K_y(i)\Delta y(i-1) + K_y(i-1)\Delta y(i)}{\Delta y(i)\Delta y(i-1)[\Delta y(i) + \Delta y(i-1)]} - \frac{0.5(k_2 - k_1) w_s}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right) C_{k,\ell}(i, j) \\
&+ \left(\frac{K_y(i)}{\Delta y(i)[\Delta y(i) + \Delta y(i-1)]} - \frac{0.5 k_1 w_s}{k_1 \Delta y(i) + k_2 \Delta y(i-1)}\right) C_{k,\ell}(i+1, j)\Bigg) \qquad (3.7.6)
\end{aligned}
$$

$i = n$

$$
\begin{aligned}
&\left[\frac{K_y(n-1)}{\Delta y(n-1)^2} + \frac{0.5(k_2 - k_1)}{(k_1 + k_2)\Delta y(n-1)}\right] C_{k,\ell}(n-1, j+1) \\
&- \left[\frac{1}{\Delta t} + \frac{K_y(n-1)}{\Delta y(n-1)^2} + \frac{0.5(k_2 - k_1) w_s}{(k_1 + k_2)\Delta y(n-1)} - \frac{(1-\alpha_2) w_s}{\Delta y(n-1)} + \frac{k_1(1-\alpha_2) w_s^2}{(k_1 + k_2) K_y(n-1)}\right] C_{k,\ell}(n, j+
\end{aligned}
$$

$$= -0.5(ku_a(n)(C_{k-1,\ell}(n,j) + C_{k-1,\ell}(n,j+1)) + \ell\, w_a(n)(C)_{k,\ell-1}(n,j)$$

$$+ C_{k,\ell-1}(n,j+1)) + k(k-1)K_x(n,j)(C_{k-2,\ell}(n,j) + C_{k-2,\ell}(n,j+1))$$

$$+ \ell(\ell-1)K_z(n,j)(C_{k,\ell-2}(n,j) + C_{k,\ell-2}(n,j+1))) \Bigg[\Bigg(\frac{K_y(n-1)}{\Delta y(n-1)^2}$$

$$+ \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(n-1)}\Bigg)C_{k,\ell}(n-1,j) - \Bigg(\frac{1}{\Delta t} - \frac{K_y(n-1)}{\Delta y(n-1)^2} - \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(n-1)}$$

$$+ \frac{(1-\alpha_2)w_s}{\Delta y(n-1)} - \frac{k_1(1-\alpha_2)w_s^2}{(k_1+k_2)K_y(n-1)}\Bigg)C_{k,\ell}(n,j)\Bigg] - \Bigg(\frac{1}{\Delta y(n-1)}$$

$$- \frac{k_1 w_s}{(k_1+k_2)K_y(n-1)}\Bigg)\gamma_2(W_{2k,\ell}(j) + W_{2k,\ell}(j+1)) \qquad (3.7.7)$$

For particles deposited on the bed:

$$W_{2k,\ell}(j+1) = W_{2k,\ell}(j) + (0.5ku_a(n)(W_{2k-1,\ell}(j) + W_{2k-1,\ell}(j+1))$$

$$+ 0.5\ell w_a(n)(W_{2k,\ell-1}(j) + W_{2k,\ell-1}(j+1)) \qquad (3.7.8)$$

$$+ \alpha_2 w_s C_{k,\ell}(n,j) - \gamma_2 W_{2k,\ell}(j))\Delta t$$

$w_s < 0$ particles floating on the free surface:

$$
\begin{aligned}
W_{1k,\ell}^{(j+1)} = W_{1k,\ell}^{(j)} &+ (0.5ku_a(1)(W_{1k-1,\ell}^{(j)} + W_{1k-1,\ell}^{(j+1)}) \\
&+ 0.5\ell w_a(1)(W_{1k,\ell-1}^{(j)} + W_{1k,\ell-1}^{(j+1)}) \\
&- \alpha_1 w_s C_{k,\ell}^{(1,j)} - \gamma_1 W_{1k,\ell}^{(j)} \\
&+ 0.5k(k-1)K_{xw}(C_{k-2,\ell}^{(1,j)} + C_{k-2,\ell}^{(1,j+1)}) \\
&+ 0.5\ell(\ell-1)K_{zw}(C_{k,\ell-2}^{(1,j)} + C_{k,\ell-2}^{(1,j+1)}))\,\Delta t
\end{aligned}
\tag{3.7.9}
$$

$w_s<0$ particles in suspension:

$i=1$

$$
\begin{aligned}
&-\left[\frac{1}{\Delta t} + \frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)} + \frac{(1-\alpha_1)w_s}{\Delta y(1)} + \frac{(1-\alpha_1)k_2w_s^2}{(k_1+k_2)K_y(1)}\right]C_{k,\ell}^{(1,j+1)} \\
&+\left(\frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\,\Delta y(1)}\right)C_{k,\ell}^{(2,j+1)} \\
&= -0.5(ku_a(1)(C_{k-1,\ell}^{(1,j)} + C_{k-1,\ell}^{(1,j+1)}) + \ell w_a(1)(C_{k,\ell-1}^{(1,j)} \\
&\quad + C_{k,\ell-1}^{(1,j+1)}) + k(k-1)K_x(1,j)(C_{k-2,\ell}^{(1,j)} \\
&\quad + C_{k-2,\ell}^{(1,j+1)}) + \ell(\ell-1)K_z(1,j)(C_{k,\ell-2}^{(1,j)} + C_{k,\ell-2}^{(1,j+1)}))
\end{aligned}
$$

$$-\Bigg(\Bigg(\frac{1}{\Delta t} - \frac{K_y(1)}{\Delta y(1)^2} - \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)} - \frac{(1-\alpha_1)w_s}{\Delta y(1)} - \frac{(1-\alpha_1)k_2w_s^2}{K_y(1)}\Bigg)C_{k,\ell}(1,j)$$

$$+\Bigg(\frac{K_y(1)}{\Delta y(1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(1)}\Bigg)C_{k,\ell}(2,j)\Bigg) - \Bigg(\frac{1}{\Delta y(1)}$$

$$+\frac{k_2w_s}{(k_1+k_2)\Delta y(1)}\Bigg)\gamma_1(W_{2k,\ell}(j) + W_{2k,\ell}(j+1)) \qquad (3.7.10)$$

$i=2$ to $n-1$ same as Eq. (3.7.6)

$i=n$

$$\Bigg(\frac{K_y(n-1)}{\Delta y(n-1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(n-1)}\Bigg)C_{k,\ell}(n-1,j+1)$$

$$-\Bigg(\frac{1}{\Delta t} + \frac{K_y(n-1)}{\Delta y(n-1)^2} + \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(n-1)} - \frac{w_s}{\Delta y(n-1)} + \frac{k_1w_s^2}{(k_1+k_2)K_y(n-1)}\Bigg)C_{k,\ell}(n,j+1)$$

$$= -0.5(ku_a(n)(C_{k-1,\ell}(n,j) + C_{k-1,\ell}(n,j+1)) + \ell w_a(n)(C_{k,\ell-1}(n,j)$$

$$+ C_{k,\ell-1}(n,j+1)) + k(k-1)K_x(n,j)(C_{k-2,\ell}(n,j) + C_{k-2,\ell}(n,j+1))$$

$$+ \ell(\ell-1)K_z(n,j)(C_{k,\ell-2}(n,j) + C_{k,\ell-2}(n,j+1))) - \Bigg(\Bigg(\frac{K_y(n-1)}{\Delta y(n-1)^2}$$

$$+\frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\Delta y(n-1)}\Bigg)C_{k,\ell}(n-1,j) + \Bigg(\frac{1}{\Delta t} - \frac{K_y(n-1)}{\Delta y(n-1)^2}$$

$$- \frac{0.5(k_2-k_1)w_s}{(k_1+k_2)\,\Delta y(n-1)} + \frac{w_s}{\Delta y(n-1)} - \frac{k_1 w_s^2}{(k_1+k_2)K_y(n-1)} \Bigg) C_{k,\ell}(n,j)$$

(3.7.11)

Note that the solution for the fluid part of the waste can be obtained by using either equations (3.7.5-7) or Equations (3.7.9-11) only by setting w_s to zero.

The implicit schemes in Eqs. (3.7.5-7) and Eqs. (3.7.9-11) are in the form of

$$b_1 u_1 + c_1 u_2 = d_1$$

$$a_i u_{i-1} + b_i u_i + c_i u_{i+1} = d_i, \quad i = 2, 3, \ldots, n-1 \qquad (3.7.12)$$

$$a_n u_{n-1} + b_n u_n = d_n$$

or

$$[A][U] = [D] \qquad (3.7.13)$$

where [A] is a tridiagonal matrix. The system of equations is solved by the Thomas algorithm as presented by Ames (1965)

$$u_n = dn'$$

$$u_i = d_i' - c_i' u_{i+1}, \quad i=n-1,\ n-2, \ldots, 1 \qquad (3.7.14)$$

where

$$c_1' = c_1/b_1, \quad d_1' = d_1/b_1$$

$$c_{i+1}' = \frac{c_{i+1}}{b_{i+1} - a_{i+1} c_i'}$$

$$d_{i+1}' = \frac{d_{i+1} - a_{i+1} d_i'}{b_{i+1} - a_{i+1} c_i'}, \qquad i=1, 2, \ldots, n-1 \qquad (3.7.15)$$

The above numerical procedure for the solution of the equations for long term diffusion follows the Standard Crank Nicolson scheme. The only point which should be emphasized is the difference scheme employed for the term involving the fall velocity w_s. As mentioned before, different difference approximations are used for the term involving the fall velocity w_s based on the sign of w_s. This is important as will be shown in the following analysis. In the following, subscripts k and ℓ will be dropped for simplicity.

For a simple derivation of the effects of the term

$$w_s \frac{\partial C}{\partial y}$$

on the transport phenomenon, terms involving ambient currents and diffusion are deleted from Equation (3.6.10). Equation (3.6.10) then becomes

$$\frac{\partial C}{\partial t} = - w_s \frac{\partial C}{\partial y} \qquad (3.6.10a)$$

The solution to Equation (3.6.10a) is simply

$$C = f(y - w_s t) \qquad (3.7.1)$$

which indicates that given an initial distribution

$$C(y, 0) = f(y) \qquad (3.7.2)$$

the functional form of f(y) will be preserved at any instant t subjected only to a linear transformation $w_s t$. Now let us try to solve Equation (3.6.10a) by a finite difference approximation, using a forward difference for both the independent variables y and t. It is obtained

$$C(y, t+\Delta t) = C(y, t) - w_s \frac{\Delta t}{\Delta y} (C_{y+\Delta y, t} - C_{y, t}) \qquad (3.6.10b)$$

Equation (3.6.10b) is incapable of correctly predicting the concentration at time $t+\Delta t$ from a known distribution at time t. For instance, for a concentration distribution as shown in Figure (3.7.2), Equation (3.6.10b) will predict at $t+\Delta t$ a negative concentration at position A and a zero concentration at position B which is completely wrong according to the analytical solution in Equation (3.7.1). If a central difference is used for

$$\frac{\partial C}{\partial y},$$

a similar result may be found depending on the relation between the concentration distribution and grid point position. If a backward difference is used for the term

$$\frac{\partial C}{\partial y},$$

Equation (3.6.10a) becomes

$$C(y,t+\Delta t) = C(y,t) - w_s\frac{\Delta t}{\Delta y}(C_{y,t} - C_{y-\Delta y,t}) \qquad (3.6.10c)$$

Critical points such as A and B in Figure (3.7.2) can again be tested. The results show that at $t+\Delta t$, the concentration at A will be zero, and at B the concentration will increase which is exactly what it should be. Following the same argument a forward difference should be used for

$$w_s\frac{\partial C}{\partial y}$$

term in the finite difference approximation for solving Equation (3.6.10a) if $w_s < 0$.

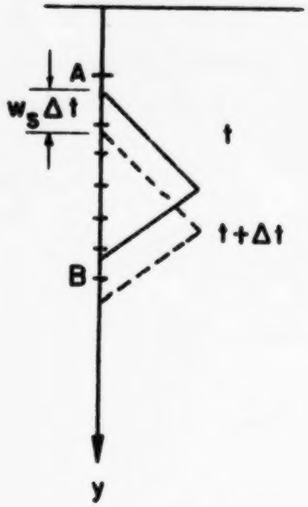


Figure 3.7.2 Definition Sketch

3.7.2 Computer Program

Using the numerical procedures in Section 3.7.1, a computer program has been developed for the prediction of the mixing characteristics in the various phases of dispersion when waste is discharged from a barge into the ocean. A flow chart of the program is shown in Figure 3.7.3. The input sequences and detailed explanations of the input and output symbols are presented in Appendix A. Attention should be called to the many options of printing and graphing in the outputs, to whether or not built in suggested coefficients are to be used, and to the options of terminating the computation at the end of different phases of dispersion. In the following, some of the details of the program are discussed.

3.7.2.1 Empirical Coefficients

For each of the three barge operations, values of a package of empirical coefficients introduced in the formulations are needed. A set of coefficients are built into the program based on either available knowledge or educated guess. These are subject to change when better estimates are available through experiments. The user of the program has the option of inputting his own estimates of the coefficients.

In Barge Operation 1, the entrainment coefficient ALPHA0 is set to be 0.235 which is the mean of the best fit values from numerical simulation on the experimental data in density stratified ambient experiments in this study. It ranges from 0.21 up to 0.265 as will be discussed in Section V. The coefficient is believed to be accurate to at most two digits. BETA is set to 0. which is believed true when the solid concentrations are relatively low. CM is set to 1. CD, CD3 and CD4 are estimated to be 0.5, 0.1 and 1.0, from drag coefficient diagrams for sphere, spheroidal wedge and circular plate respectively. For the coefficients GAMA, CDRAG, CFRIC, ALPHAC, FRICTN and F1, estimates are based only on educated guesses. More extensive experiments are needed to provide these coefficients.

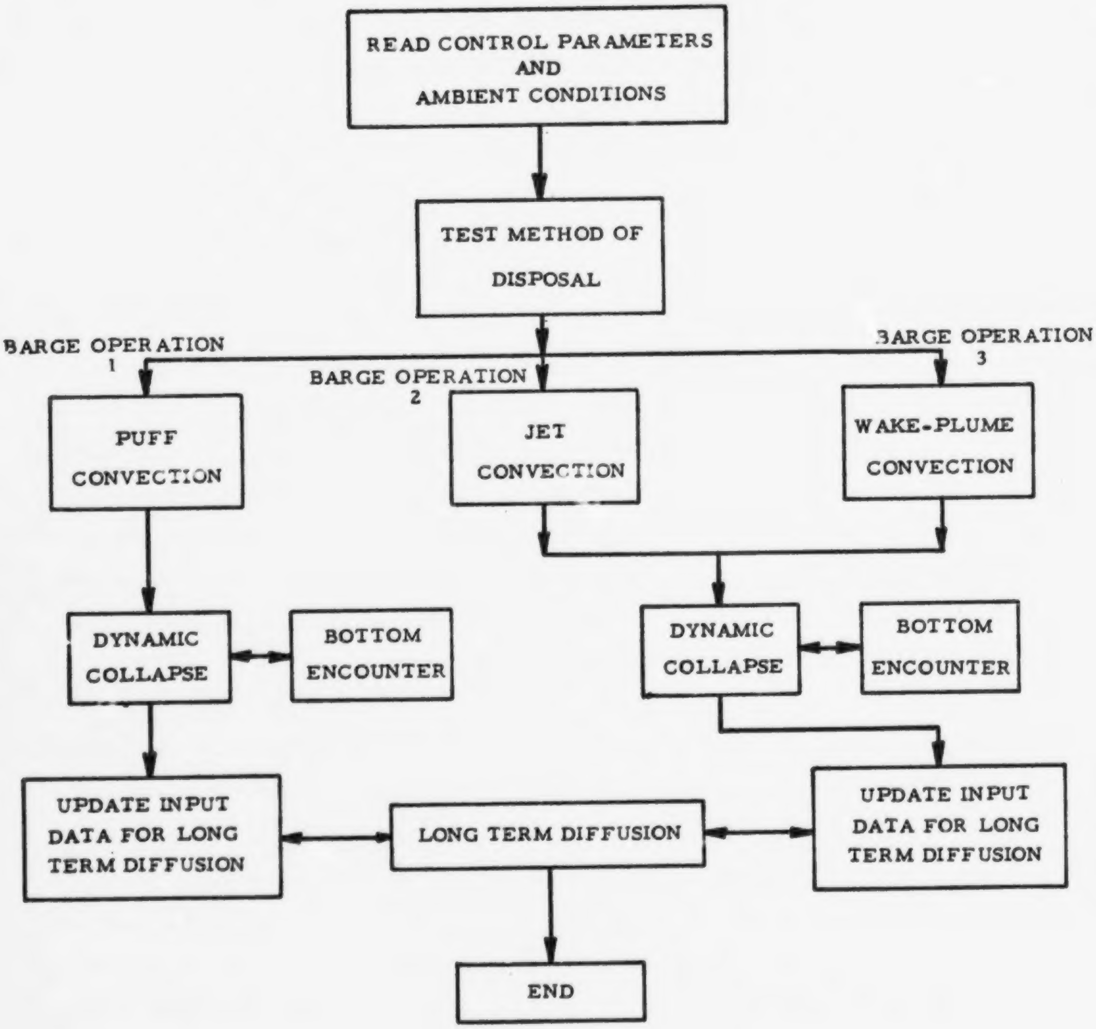


Figure 3. 7. 3 Flow Chart for the Computer Program

In Barge Operation 2, in the jet convection phase the entrainment coefficients for a momentum jet and a two-dimensional thermal, ALPHA1 and ALPHA2, are set to 0.0806 and 0.3536 respectively. The values are from Abraham (1970) after correction by a numerical factor arising from the different similarity distributions for density deficiency, velocity, etc. used in Abraham's and the present formulations.

The settling coefficient BETA is set to zero. The drag coefficient CD is set to be 1.3 as obtained from the drag diagram for a two-dimensional cylinder. The above coefficients are considered quite good since numerical simulations using those coefficients fit the experimental data well. In the dynamic collapse phase, the entrainment coefficient ALPHA3 is again set to 0.3536. The approximation should be good if the shape of the elliptical cylinder is not too far off from a circular cylinder. The drag coefficients CD3 and CD4 for a two-dimensional wedge and two-dimensional plate are estimated to be 0.2 and 2.0 from the drag coefficient diagram. There is again no experimental information on GAMA, CDRAG, CFRIC, FRICTN and F1. The estimated values are accordingly subject to change when better knowledge is available.

In Barge Operation 3, C1 and C2 are important in determining the initial mixing and are estimated to be 0.6 and 4 respectively. Since there is no field data, these coefficients are set to the above values in the numerical simulation. Their choice can be made with confidence only when adequate experimental data is available. For the convective descent phase, the entrainment coefficient ALPHA is set to be 0.3536. The drag coefficients CD1 and CD2 are again estimated to be 1.3 and 0.5 from drag coefficient diagrams for a two-dimensional cylinder and a two-dimensional wedge. For the dynamic collapse phase Barge Operation 2 and Barge Operation 3 use the same coefficient.

For the long term diffusion phase, if there is no ambient current near the free surface and the bed, the boundary absorbency coefficients ALFA1 and ALFA2 should be 1 and the re-entrainment coefficients GAMA1 and

GAMA2 should be 0. However, if there is a current near the boundaries, the coefficients may take on other values. The dissipation parameter ALAMDA is set to 0.001 which is the value for the ocean (see Section 3.2.2). It may be smaller for inland lakes.

3.7.2.2 Transition between Different Phases and Input of Solid Particles to Long Term Diffusion

During the mixing processes beginning with the discharge of waste material and ending with the end of long term diffusion, there is no clear demarcation between the different stages of convection, collapse and long term diffusion. In the computer program, the first stage of convection is either terminated by bottom encounter or when the cloud reaches the first neutrally buoyant position for Barge Operations 1 and 3, and the first horizontal position of the jet trajectory for Barge Operation 2. The dynamic collapse phase for all three barge operations stops when the estimated horizontal spreading due to diffusion is larger than that due to dynamic collapse. In this second stage of computation, the computation can switch from dynamic collapse to bottom encounter if the cloud or plume hits the bottom or from bottom encounter back to dynamic collapse if the reaction force at the bed is less than or equal to zero.

During the convection and collapse phases, the mechanism of entrainment is important in the mixing phenomenon. In the dynamic collapse and bottom encounter phases, the entrainment due to both convection and collapse are included in the formulation. However, it is believed that the entrainment is dominated by that due to convection and collapse at the beginning and end of dynamic collapse respectively. In the program, it is assumed that the entrainment is solely due to collapse after either the cloud reaches the bottom or the cloud passes the second neutrally buoyant position. Also after the waste pool starts to collapse, the cloud or plume is more like a disk or a two-dimensional plate and the added mass coefficient in the vertical direction must be modified. It is postulated herein that C_M in the vertical direction is increased by the ratio of b/a. This is equivalent to taking the hydrodynamic mass in the vertical direction to be proportional to b^3 in the case of a disk and to b^2L in the case of a plate. While the numerical value of C_M is uncertain, this functional behavior is expected to be correct.

For a reasonable presentation of the characteristics of the waste cloud or plume in these two stages, a maximum of 600 computation steps is allowed; 100 to 200 steps for the convection stage and 100 to 400 points for the collapse or bottom stage. DINCR1 and DINCR2 are controls of integration steps for the first and second stages respectively. The computer proceeds during the first stage with step size of DINCR1 times a program estimated step size (based on density gradient and/or depth) until either a normal termination (see previous paragraph) or the computation exceeds 600 steps. At that moment the computer prints DINCR1, the step size, the number of computation points and checks whether the computation points are satisfactory. If it is not, DINCR1 is modified and the computation is started over. The computer enters the second stage only if both the physical and the computation points criteria are fulfilled. In analogy to the first stage, the computation of the second stage is completed by repeated trials of modifying the step size to fulfill both the physical and computation points criteria. For each stage a maximum of five trials is allowed. If the computation is not satisfactory within five trials, the computer prints a diagnosis and exits. Then by the trial history of DINCR1 or DINCR2, the user should be able to pick a best trial value for DINCR1 or DINCR2 and start the program over. Situations requiring more than five trials have not been observed in any normal run.

At the end of the dynamic collapse phase, the waste material is considered to be dynamically passive and long term diffusion takes over. However, for those solid particles which settled out of the waste cloud or plume in the first and second stages, long term diffusion must start whenever they are out of the main cloud. Hence the long term diffusion computation in the program can be further divided into two phases: before and after the end of the dynamic collapse phase. Before the end of dynamic collapse, there are inputs of solid particles into the long term diffusion model while the diffusion proceeds. After the end of collapse only diffusion and settling are involved.

For Barge Operation 1, if there are solid particles settled out of the main cloud between two time steps, the settled particles are considered to form a circular slab of the same radius as the cloud right beneath or above the cloud depending on the sign of the fall velocity. The thickness can be evaluated by the fall velocity and positions of the cloud. While it is possible to input each slab individually into the long term diffusion model and let the model perform the calculations for diffusion and settling between successive inputs it is much more efficient in terms of computation time to wait until several or possibly many slabs have settled out. A characteristic time interval given by the settling velocity and the vertical grid spacing in the diffusion model is chosen and all slabs which settle out of the cloud during each such period are inputted into the long term diffusion model simultaneously. However each slab is updated to the time of input by allowing it to settle, move with the ambient currents and diffuse according to a simple diffusion law. During each such time interval, the solid particles already in the long term diffusion model undergo several time steps of diffusion. In this manner, the solid particles settled out of the cloud are updated toward the end of dynamic collapse. At that moment all the solid particles which still remain in the cloud are thrown into the long term diffusion model all at once. As for the fluid part of the waste material, it is thrown into the long term diffusion model only at the end of dynamic collapse. For input of a circular slab of solid particles into the long term diffusion model, the following formulas are used

$$C_{00} = C\pi b^2$$

$$C_{10} = xC_{00}$$

$$C_{01} = zC_{00}$$

$$C_{20} = C_{00}\left(x^2 + \frac{1}{4}b^2\right)$$

$$C_{02} = C_{00}\left(z^2 + \frac{1}{4}b^2\right)$$

$$C_{11} = xzC_{00} \qquad (3.7.2.1)$$

where C is the concentration, b is the radius, x and z are the centroid of the slab.

For Barge Operations 2 and 3, because of the limited discharge time, attention should be called to the front and tail of the plume in inputting solid particles to the long term diffusion model. In Figure 3.7.4, curve ABC shows the front of the plume in space-time, point B is where solid particles start to settle and point C is when long term diffusion takes over for the front of the plume. Curve A'B'C' shows the tail of the plume. Starting from T_1, there should be solid particles to be put into the long term diffusion model. The solid particle slabs are thrown into the long term diffusion model at intervals of Δt. It is therefore seen that at $T_1 + \Delta t$, there are slabs only below positions i, i+1 and i+2 to be taken care of. As time moves from $T_1 + \Delta t_1$ to $T_1 + \Delta t_1 + \Delta t_2$, the number of slabs increases as shown in the figure. When time is larger than T_2, solid particles inside the main plume have also to be put into the long term diffusion. And when time is larger than T_3, there no longer are any slabs under position j as shown in the figure. When time is larger than T_4, all the solid particles are in the long term diffusion model.

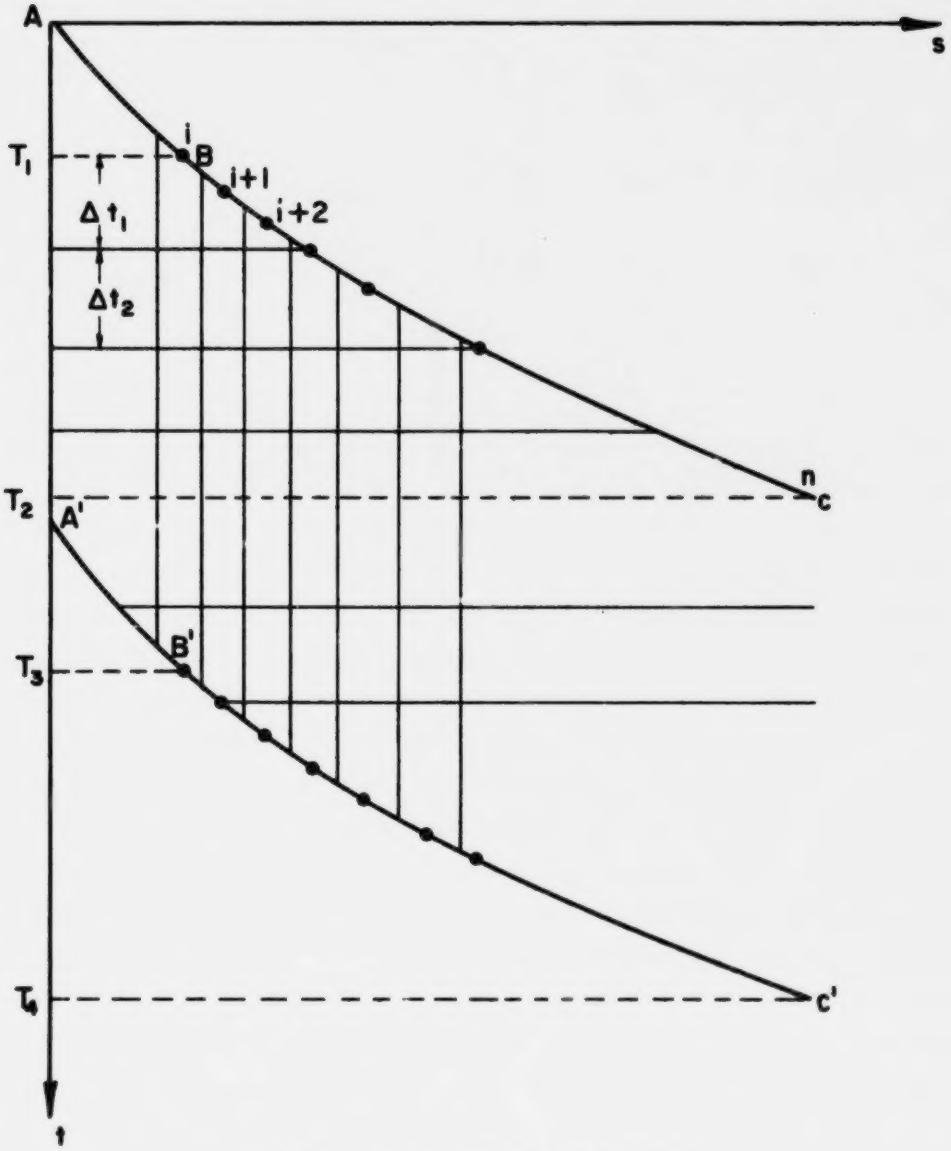


Figure 3.7.4 Definition Sketch

For inputting the solid particle slab into the long term diffusion model, rectangular horizontal slabs just above or beneath the plume are used according to the plume sizes, positions, solid particle fall velocity and time interval Δt. For computing the moments, the following formulas are used

$$
\begin{aligned}
C_{00} &= C2bL \\
C_{10} &= xC_{00} \\
C_{01} &= zC_{00} \\
C_{20} &= C_{00}\left(x^2 + \frac{L^2}{12}\cos^2\gamma + \frac{b^2}{3}\sin^2\gamma\right) \\
C_{02} &= C_{00}\left(z^2 + \frac{L^2}{12}\sin^2\gamma + \frac{b^2}{3}\cos^2\gamma\right) \\
C_{11} &= C_{00}\left(xz + \sin\gamma\cos\gamma\left(\frac{L^2}{12} - \frac{b^2}{3}\right)\right) \qquad (3.7.2.2)
\end{aligned}
$$

where b is the half width of the plume, L is the length of the plume segment, x and z are the horizontal centroid and γ is the angle between L and the x-axis.

After all the waste material is in the long term diffusion model (at the end of dynamic collapse for Barge Operation 1 and at the time when the tail of the plume comes to the end of dynamic collapse for Barge Operations 2 and 3), the model will continue to perform the dispersion calculations until terminated either when the time exceeds a read-in time limit or by the fact that a substantial amount of the solid particles have settled to the boundaries or that the fluid waste is well mixed vertically into the water column.

In the long term diffusion part of the program, special consideration has been given to the change of grid size and computation time step according to the characteristics of the diffusing pool such as the vertical spread of the plume, the fall velocity of the solid particles and the vertical diffusion coefficient. The change is automatically done in the program. The vertical grid lines are chosen to be close together within and near the waste material and farther apart where there is little waste. Thus, for example, if at the beginning of long term diffusion, all the waste is within a thickness of 5 feet in an ocean of depth 100 feet, the grid lines would be packed close together within and around the cloud. As the diffusion and settling proceeds however, the grid automatically changes to accommodate. The time step of integration is also automatically controlled based on the characteristics of the waste pool and the diffusion coefficient. However a provision for change by the user is incorporated.

It should be remarked that the computer program developed herein must not be regarded as the ultimate achievable in the solution of the basic problem. Modifications and improvements are possible which can greatly enhance its utility. It should further be pointed out that the program is not designed to be able to handle all situations and any user must first fully understand its limitations. For example, it is assumed in the program that the waste will go through a stage of convective descent. Thus, the gross density of the waste discharged must be greater than the ambient density and the initial downward velocity of the waste should be larger than 0. Moreover, when the convective descent phase ends, either at the first neutrally buoyant position for Barge Operations 1 and 3 or a horizontal position in Barge Operation 2, the local ambient may not be stratified. In that event the program will bypass the collapse phase and go directly to the long term diffusion phase. This is not necessarily always valid because the pool may return upward into a density gradient and collapse resulting in different predictions. In the latter case the program user may force the collapse simply by recalculating the case after first introducing a very slight density gradient at the proper location.

SECTION IV

EXPERIMENTAL INVESTIGATION

4.1 Objective and Scope of Experimental Investigations

The mathematical model developed in this study is intended to predict the physical behavior of the waste material discharged from a barge into the ocean. To test the applicability of the theory, experiments are needed to confirm the hypotheses made and to obtain the coefficients introduced in the formulation. For a complete experimental check, a large number of experiments would have to be performed in a complex ambient with cross currents and density stratifications similar to that of the prototype. However, in the present study, only a set of simplified but representative preliminary experiments were performed in a stagnant laboratory tank with or without density stratifications. Results of the experiments were used to evaluate mainly the entrainment coefficient and test the applicability of the mathematical model up to the onset of the long term diffusion phase.

4.2 Apparatus and Procedure

4.2.1 Ambient Condition

Experiments were performed in a tank 9 inches wide, 15 inches deep and 40 inches long. For uniform density ambient runs, the tank was filled with cold water. For runs with density stratification, the tank was first filled to half depth with cold water, then hot water was gently introduced on top of the cold water through a cup residing at the water surface, with holes on the sidewalls near its bottom. The position of the cup was adjusted as the water surface rose. Thus the lighter hot water spread out horizontally on the heavier cold water. When the water level reached the top of the tank, there were two layers of water with an interface of fairly strong temperature gradient. To destroy the interface and obtain a nearly linear gradient, a piece of plastic cloth about 4 inches high and 9 inches wide was put vertically with its middle at the interface and towed slowly horizontally by two rods attached to the ends of the plastic cloth. After about 10 minutes, the turbulence generated by the towing of the plastic cloth died away and a nearly linear stratification was obtained. The temperature distribution was measured and the density stratification was calculated from the temperature distribution.

4.2.2 Discharge Material

Four different discharge materials were used in the experiments, namely: a) mud, b) digested sewage sludge c) dredge spoil and d) salt solution. Mud was obtained by mixing a quantity of earth with water. The digested sludge was provided by EPA and LA County Sanitation District. The coarser particles in the mud and larger sticks in the sewage sludge were filtered off by a screen of about 1/32 inch mesh size. The dredge spoil, obtained at San Francisco Bay, was provided by the Corps of Engineers at San Francisco. The particles in the mud were in the range of clay to silt, and those in the dredge spoil were small sands. The mud and dredge spoil are non-cohesive in nature. The digested sewage sludge consisted of very fine particles up to about 1/32 inch in size and it seemed to be slightly sticky at high concentration. Salt solution is obtained by dissolving table salt into water.

4.2.3 Procedure and Data Reduction

Three different modes of discharge were used including i) an instantaneous three-dimensional slug, ii) a continuous discharge from a horizontally travelling vertical jet, and iii) an instantaneous two-dimensional line. The first mode simulating Barge Operation 1 was achieved by injecting the waste material through a modified syringe, cut-off at the shoulder and covered by a screen of about 1/32 inch mesh size. The special feature of the syringe was that the screen could hold the waste material in the syringe by surface tension when the syringe was held in the vertical position in air. For injection, the syringe was lowered and when the front of the syringe was just below the water surface, the waste material was injected downward by the plunger. The second mode of discharge simulating Barge Operation 2 was achieved by discharging the waste material continuously through a vertical glass tube fixed on a carriage which was towed horizontally along the center line of the tank by a system consisting of a cable, pulleys, and a variable speed drill motor. The glass tube is connected by a Tygon tube to a constant head Mariotte tank which provides constant discharge. In the third mode, a half-cylindrical trough filled with the waste spanning the width of the tank was inverted to simulate a two-dimensional puff.

For the experiments, the aforementioned materials were made to various densities by mixing with water. The density was measured by weighing a known volume of waste material or by a hydrometer. After the waste material was injected into the water, the position and size was recorded by time lapse photography. The timing of the pictures taken was indicated by either a clock placed in front of the tank or a wax ball of known fall velocity set free in the tank before the injection. The intervals between successive pictures were variable depending on the time scale of the dynamics. The shortest interval achieved was about 0.3 second.

For the position and size of the waste material after injection, the time-lapse pictures on the 35 mm film were projected frame by frame by an enlarger. The pictures were adjusted to be one-third of life size. A sheet of graph paper was lined up accurately on each frame using the markers on the tank as a guide. The outlines of the cloud were then traced.

For injection modes 1 and 3, the distance of the centroids of the cloud below the injection point and its horizontal and vertical dimensions were measured off from the traced picture. For each position, the corresponding time starting from the injection was obtained from the clock or the position of the wax ball, and the position-time plot was extrapolated to the point of injection. The initial velocity for each run was also estimated from the slope of the position-time plot. For injection mode 2, the traveling velocity of the jet was measured from the horizontal position vs. time plot of the glass tube, and the trajectory and size of the plume was obtained by taking the average of several traces.

4.3 Results and Discussions

Seventy experiments were performed in this investigation. The experimental parameters and density stratification profiles are presented in Tables 4.1 and 4.2. The run number designations listed in the tables are as follows: The first letter in the designation signifies the nature of the waste material: M for mud, S for sludge, D for dredge spoil, and N for salt water. The subscript on the first letter signifies the mode of discharge: blank for three-dimensional instantaneous, 2 for two-dimensional instantaneous and j for jet. The second entry in the designation signifies the density stratification in the receiving water: 0 for uniform and S for stratified. The last entry is just the numerical sequence within each group of experiments.

4.3.1 Instantaneous Release of a Three-Dimensional Slug

The pertinent parameters on those runs involving an instantaneous release of a three-dimensional slug, i.e., simulation of Barge Operation 1, are summarized in Table 4.1a. Those experiments in Table 4.1a can be subdivided into two groups a) with uniform ambient and b) with stratified ambient. The primary purposes of the runs in the first category are to obtain an estimate of the entrainment coefficient α and to attempt a correlation of the entrainment coefficient with other measurable quantities in the experiments. The experiments in the second category are used to verify the mathematical model.

In the formulation of the mathematical model for Barge Operation 1, it was assumed that the cloud is always in a hemispherical shape. It was noted in the experiments that the initial momentum and buoyancy sometimes generated a vortex inside the cloud, and the shape of the cloud was strongly affected by the strength of the vorticity. The increase of vorticity changed the shape of the cloud from spherical to hemispherical

TABLE 4. 1a

Summary of Experimental Parameters

Run No.	V(cc)	ρ (gm/cc)	α
M-0- 1	.86	1.053	.29
M-0- 2	.86	1.053	.39
M-0- 3	.86	1.143	.35
M-0- 4	.86	1.143	.25
M-0- 5	.86	1.217	.25
M-0- 6	.86	1.217	.26
M-0- 7		1.053	.29
M-0- 8	.372	1.053	.40
M-0- 9	.372	1.053	.27
M-0-10	.372	1.217	.27
S-0- 1		1.077	.34
S-0- 2		1.139	.45
S-0- 3		1.11	.25
S-0- 4		1.11	.40
S-0- 5		1.11	.20
S-0- 6		1.139	.19
S-0- 7	.74	1.074	.22
S-0- 8	.74	1.108	.19
S-0- 9	3.66	1.13	.18
S-0-10	3.66	1.016	.44
S-0-11	5.16	1.13	.23
S-0-12	5.16	1.108	.19
S-0-13	8.55	1.108	.16
D-0- 1	3.66	1.997	.25
D-0- 2	0.86	1.894	.26
D-0- 3	3.66	1.997	.23
D-0- 4	NA	1.997	.30

(Table 4. 1a continued)

Run No.	V(cc)	ρ (gm/cc)	u (fps)	α
M-S-1	3.66	1.432	0.294	.265
M-S-2	3.66	1.202	0.190	.265
M-S-3	3.66	1.290	0.236	.22
M-S-4	3.66	1.290	0.318	.23
S-S-1	3.66	1.128	0.350	.235
S-S-2	3.66	1.128	0.292	.25
S-S-3	3.66	1.1233	0.244	.22
S-S-4	3.66	1.0655	0.143	.255
S-S-5	3.66	1.0655	0.152	.255
S-S-6	3.66	1.0655	0.242	.25
S-S-7	3.66	1.1233	0.156	.26
N-S-1	3.66	1.080	.210	.21
N-S-2	3.66	1.080	.181	.25
N-S-3	3.66	1.179	.240	.22
N-S-4	3.66	1.179	.250	.225
N-S-5	3.66	1.179	.3	.230

V = volume of waste discharged
ρ = overall density of waste discharged
α = observed entrainment coefficient
u = velocity of waste at discharge point

TABLE 4.1b

Summary of Experimental Parameters

Run No.	D_i (in)	U_j(ft/sec)	U_b(ft/sec)	$k=U_j/U_b$	ρ(gm/cc)	F
Nj-0-1	.0725	3.86	.442	8.73	1.1455	18.40
Nj-0-2	.0725	3.86	.432	8.95	1.1455	18.40
Nj-0-3	.0725	3.86	.238	16.20	1.1455	18.40
Nj-0-4	.0725	3.86	.275	14.00	1.1455	18.40
Nj-0-5	.0725	3.86	.216	17.85	1.1455	18.40
Sj-0-1	.0725	2.05	.142	14.42	1.030	690
Sj-0-2	.0725	2.05	.146	14.05	1.030	690
Sj-0-3	.0725	2.05	,146	14.05	1.030	690
Sj-0-4	.125	.593	.145	4.09	1.030	3.5
Sj-0-5	.125	.593	.146	4.06	1.030	3.5
Sj-0-6	.125	.593	.140	4.23	1.030	3.5
Nj-S-1	.0725	3.7	.150	24.64	1.134	19.00
Nj-S-2	.0725	3.7	.464	8.00	1.134	18.00
Nj-S-3	.0725	3.7	.276	13.40	1.134	18.00
Nj-S-4	.0725	3.7	.135	27.40	1.134	18.00
Nj-S-5	.0725	3.2	.141	22.70	1.163	9.00
Nj-S-6	.0725	3.7	1.03	3.60	1.163	12.00
Nj-S-7	.0725	3.2	.141	22.70	1.163	9.10
Nj-S-8	.0725	3.7	.341	10.85	1.163	12.00
Nj-S-9	.0725	3.2	.258	12.40	1,163	8.70
Nj-S-10	.0725	3.2	.45	7.12	1.163	8.70
Nj-S-11	.0725	3.2	.3	10.65	1.163	8.85

(Table 4.1b continued)

Run No.	D_i (in)	U_j(ft/sec)	U_b(ft/sec)	k	ρ(gm/cc)	F
Sj-S- 1	.0725	2.05	.147	17.00	1.030	540
Sj-S- 2	.0725	2.05	.146	17.12	1.030	540
Sj-S- 3	.125	.593	.153	3.87	1.030	2.6
Sj-S- 4	.125	.593	.142	4.18	1.030	3.3
Sj-S- 5	.125	.593	.138	4.30	1.030	3.3

D_i = ID of discharge tube

U_j = velocity of discharge

U_b = horizontal velocity of discharge tube

ρ = density of waste

$$F = U_j^2 / g \frac{(\rho - \rho_a(o))}{\rho} D_i$$

TABLE 4. 1c

Summary of Experimental Parameters

Run No.	ρ (gm/cc)	u (ft/sec)	α
M_2-0-1	1.171		.45
S_2-0-1	<1.128		.34
M_2-S-1	1.138	.0983	
M_2-S-2	1.138	.0865	
S_2-S-1	1.060	.095	
S_2-S-2	1.060	.126	
S_2-S-3	1.1233	.0716	

ρ = density of waste

u = velocity of waste at discharge point

α = observed entrainment coefficient

Table 4.2a. Density Stratification for Runs M-S, S-S and N-S

Run	M-S-1-2	M-S-3	M-S-4
y	ρ	ρ	ρ
0.0	0.9911	0.99125	0.99182
0.083	0.9911	0.99125	0.99183
0.166	0.9911	0.99125	0.99185
0.250	0.9911	0.99128	0.99190
0.333	0.9911	0.99142	0.99200
0.416	0.9911	0.99176	0.99225
0.500	0.9913	0.99278	0.99280
0.583	0.9922	0.99395	0.99395
0.666	0.9938	0.99505	0.99505
0.750	0.9949	0.99588	0.99588
0.833	0.9958	0.99650	0.99650
0.917	0.9965	0.99695	0.99695
1.000	0.9971	0.99725	0.99725
1.083	0.9975	0.99755	0.99755
1.168	0.9978	0.99776	0.99776

(Table 4.2a continued)

S-S-1-2	S-S-3	S-S-4-5	S-S-6	S-S-7
0.9959	0.99388	0.99422	0.99280	0.99225
0.9959	0.99389	0.99422	0.99280	0.99228
0.9959	0.99390	0.99422	0.99280	0.99233
0.9959	0.99391	0.99422	0.99281	0.99245
0.9959	0.99398	0.99430	0.99285	0.99265
0.9960	0.99440	0.99450	0.99297	0.99295
0.9961	0.99498	0.99498	0.99330	0.99335
0.9963	0.99537	0.99537	0.99386	0.99380
0.9964	0.99572	0.99572	0.99455	0.99435
0.9966	0.99600	0.99600	0.99530	0.99490
0.9967	0.99625	0.99625	0.99595	0.99548
0.9969	0.99645	0.99645	0.99651	0.99607
0.9970	0.99660	0.99660	0.99695	0.99652
0.9972	0.99669	0.99669	0.99724	0.99684
0.9976	0.99672	0.99672	0.99745	0.99715

(Table 4.2a continued)

N-S-1	N-S-2	N-S-3-4-5
0.99315	0.99285	0.99253
0.99315	0.99285	0.99253
0.99315	0.99285	0.99253
0.99315	0.99287	0.99255
0.99316	0.99289	0.99262
0.99321	0.99300	0.99281
0.99330	0.99317	0.99305
0.99345	0.99344	0.99342
0.99368	0.99368	0.99368
0.99406	0.99406	0.99406
0.99442	0.99442	0.99442
0.99480	0.99480	0.99480
0.99519	0.99519	0.99519
0.99550	0.99550	0.99550
0.99580	0.99580	0.99580

Table 4.2b. Density Stratification for Runs N_j-S and S_j-S

N_j-S-1	N_j-S-2-3-4	N_j-S-5-6	N_j-S-7	N_j-S-8	N_j-S-9-10	N_j-S-11
0.99205	0.98960	0.99500	0.99550	0.99550	0.99255	0.99333
0.99205	0.98986	0.99500	0.99552	0.99552	0.99260	0.99333
0.99205	0.99025	0.99503	0.99553	0.99553	0.99272	0.99340
0.99205	0.99080	0.99510	0.99555	0.99555	0.99295	0.99360
0.99205	0.99155	0.99521	0.99560	0.99560	0.99332	0.99390
0.99235	0.99242	0.99532	0.99562	0.99562	0.99372	0.99430
0.99280	0.99350	0.99548	0.99569	0.99569	0.99425	0.99476
0.99343	0.99435	0.99563	0.99575	0.99575	0.99480	0.99530
0.99435	0.99510	0.99581	0.99581	0.99581	0.99540	0.99590
0.99557	0.99572	0.99608	0.99591	0.99591	0.99608	0.99652
0.99645	0.99630	0.99621	0.99600	0.99600	0.99678	0.99720
0.99713	0.99680	0.99643	0.99610	0.99610	0.99748	0.99790
0.99765	0.99730	0.99668	0.99625	0.99615	0.99823	0.99865

(Table 4.2b continued)

S_j-S-1	S_j-S-2	S_j-S-3	S_j-S-4-5
0.98900	0.99020	0.98938	0.99065
0.98900	0.99020	0.98938	0.99065
0.98900	0.99021	0.98940	0.99065
0.98912	0.99025	0.98960	0.99072
0.98985	0.99065	0.99022	0.99105
0.99142	0.99165	0.99121	0.99175
0.99335	0.99335	0.99250	0.99280
0.99488	0.99488	0.99390	0.99395
0.99612	0.99612	0.99520	0.99505
0.99710	0.99710	0.99635	0.99617
0.99772	0.99772	0.99720	0.99700
0.99808	0.99808	0.99795	0.99765
0.99925	0.99925	0.99820	0.99850

Table 4.2c Density Stratification for Runs M_2-S and S_2-S

M_2-S-1	M_2-S-2 S_2-S-1	S_2-S-2	S_2-S-3
0.99438	0.99163	0.99550	0.99291
0.99439	0.99163	0.99551	0.99293
0.99439	0.99165	0.99552	0.99294
0.99440	0.99165	0.99552	0.99297
0.99441	0.99165	0.99554	0.99300
0.99448	0.99167	0.99558	0.99312
0.99460	0.99168	0.99564	0.99337
0.99475	0.99173	0.99573	0.99380
0.99500	0.99190	0.99582	0.99435
0.99530	0.99220	0.99592	0.99490
0.99565	0.99258	0.99602	0.99548
0.99615	0.99315	0.99613	0.99607
0.99670	0.99383	0.99627	0.99652
0.99710	0.99455	0.99640	0.99684
0.99744	0.99542	0.99655	0.99715

and finally to a convective vortex ring. It was also noted in the experiments that the shape of the cloud could depend on the injection mode. A single well formed cloud was not always produced; every once in a while, a cloud consisted of a better shaped front with some residue behind it, similar to the dirty thermal found by previous investigators. Although there exist anomalies in the experiments, such as dirty thermals, in general the cloud was of a shape which can be best described by a hemisphere. Most significant of all, the experiments showed no significant and consistent differences among different waste materials, with or without solid particles settling out of the cloud.

In the integral technique used in the formulation of Barge Operation 1, one of the most important items requiring experimental determination is the entrainment coefficient. From the conservation of mass equation, by assuming no settling, small density difference between the cloud and the ambient and that the entrainment is only through the front part of the hemispherical shaped cloud, the entrainment coefficient can be easily shown to be equal to the tangent of half of the angle the cloud spreads, i.e., $\alpha = \frac{b}{y}$. Strictly speaking, $\frac{b}{y}$ can be taken as the entrainment coefficient only if the assumptions are fulfilled. From the general observations made in the experiments, it is believed that this estimate for the entrainment coefficient is the best available. The estimates of entrainment coefficient from experimental data are shown in Table 4.1a. It varies from 0.16 up to 0.45, with most of its values around 0.24.

From simple dimensional analysis, it can be shown that the entrainment rate depends on the buoyancy and vorticity. However, no consistent definite correlation has been found in the present investigation. It is speculated that the entrainment rate is related to the structure and the development of the vorticity inside the cloud, a detail which is not included in the present integral approach. As will be shown later, the entrainment rate is important to the accuracy of the prediction of the waste material's final position in a stratified ambient. The entrainment rate and its relation to the buoyancy, vorticity and other parameters should be further investigated.

Since in most cases the ambient density in the ocean is stratified due to temperature and salinity variations, the adequacy of the mathematical model depends on its verification by the experiments in a stratified ambient. Experiments with instantaneous release of a three-dimensional slug in a stratified ambient are summarized in Table 4. 1a. Selected detailed results are shown in Figures 4.3.1.1-6, consisting of graphs of i) centroid locations vs. time, ii) ambient stratification, iii) vertical size vs. time and iv) horizontal size vs. time. Comparison with numerical predictions are also shown.

In the experiments for runs with uniform ambient condition, the cloud always reached the bottom and spread out horizontally there. For runs with a stratified ambient, the cloud may or may not reach the bottom, depending on the strength of the stratification. If the cloud did not reach the bottom, it was observed to first descend, then halt, return upward and oscillate very slowly. In general the cloud had initiated its horizontal collapse before it came to the first halt. From the general observation of the experiments, the transition from convective descent to dynamic collapse was found to be a continuous process; the shape of the cloud changed continuously from approximately hemispherical to approximately ellipsoidal near the neutrally buoyant position. There was no clear demarcation to separate the convective descent and dynamic collapse phases. However, the experiments clearly showed the general characteristics such as entrainment, convective descent and collapse as postulated in the formulation.

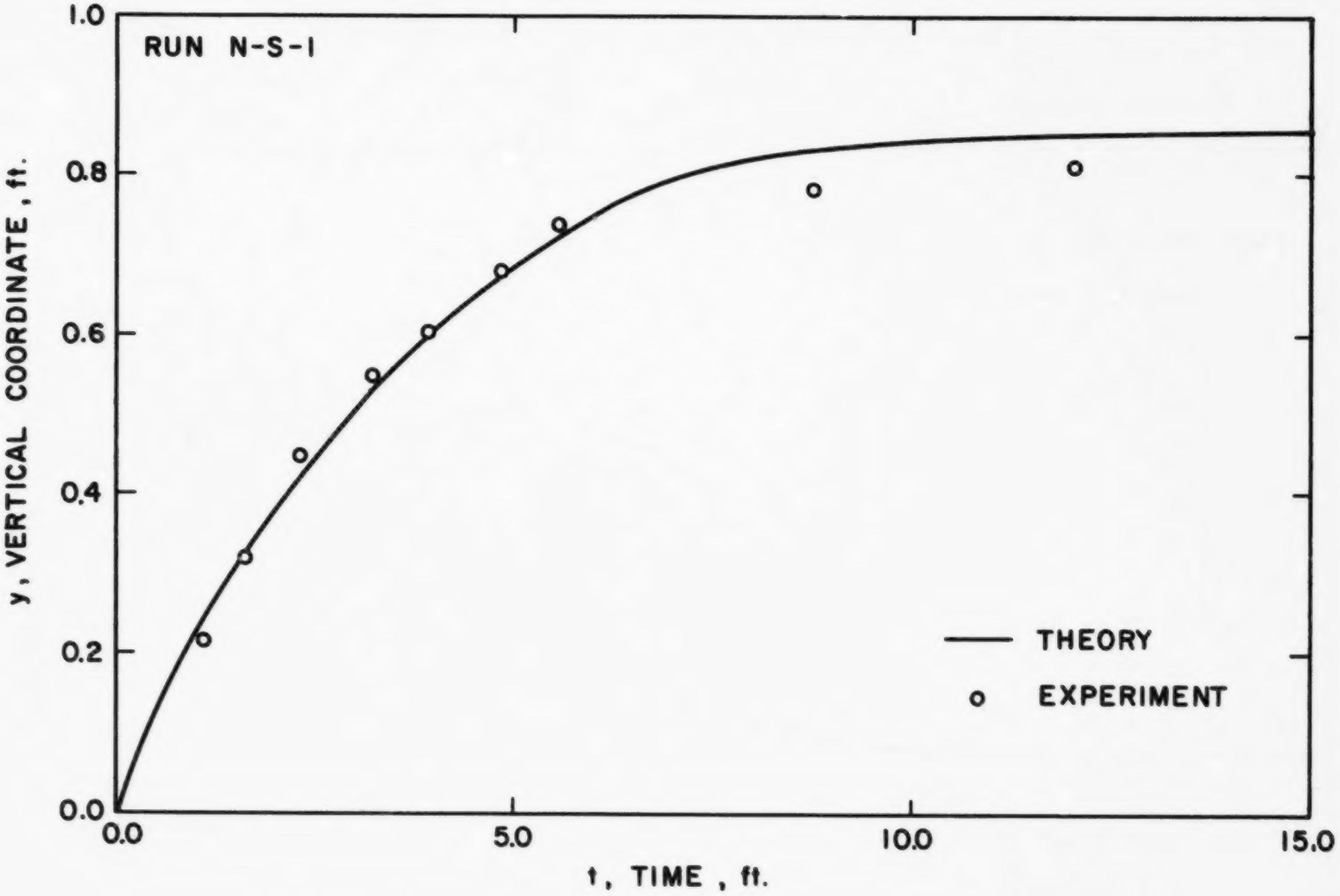


Figure 4.3.1.1 Comparison of experiment with numerical model (Run N-S-1)

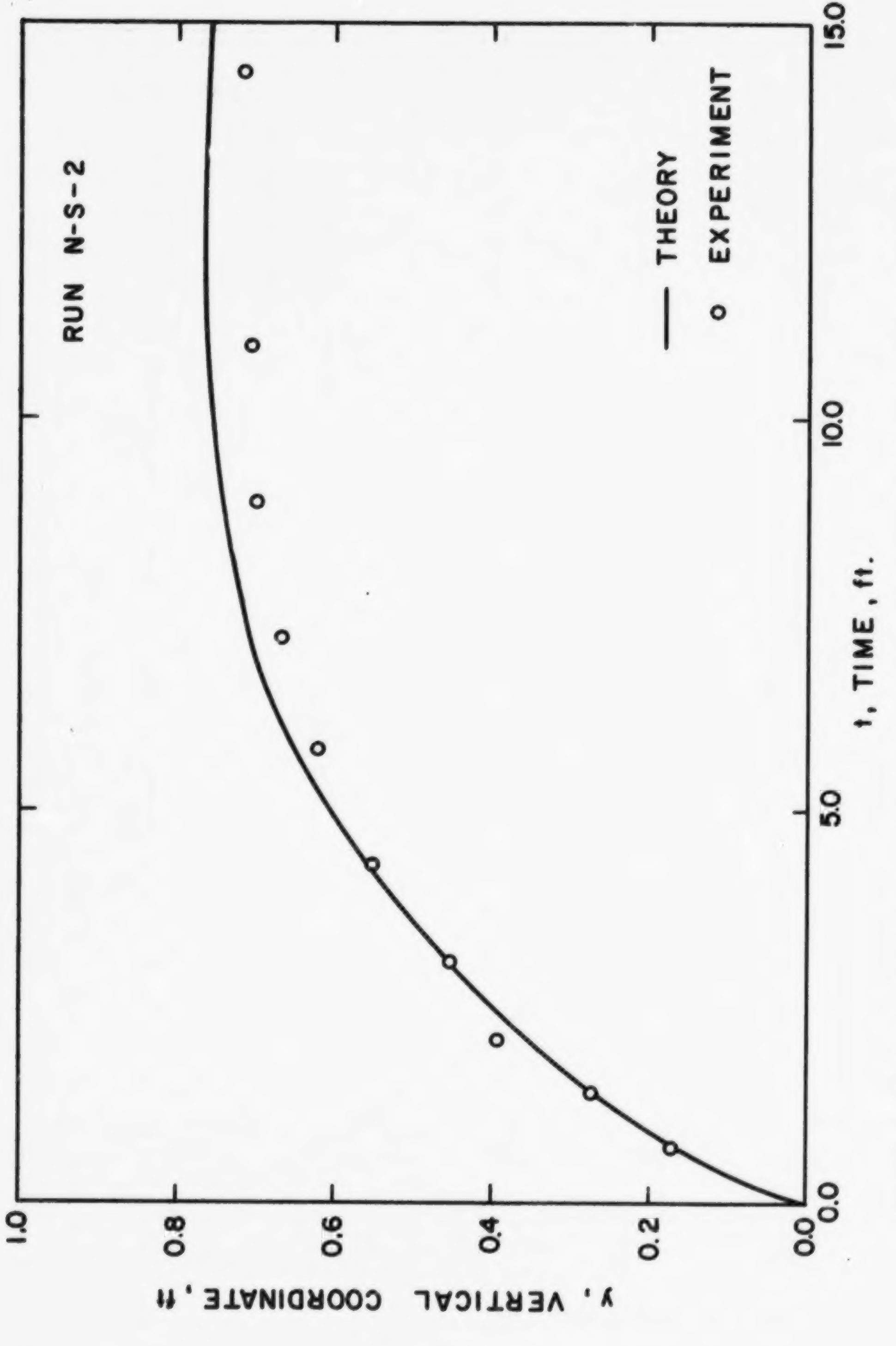


Figure 4.3.1.2 Comparison of experiment with numerical model (Run N-S-2)

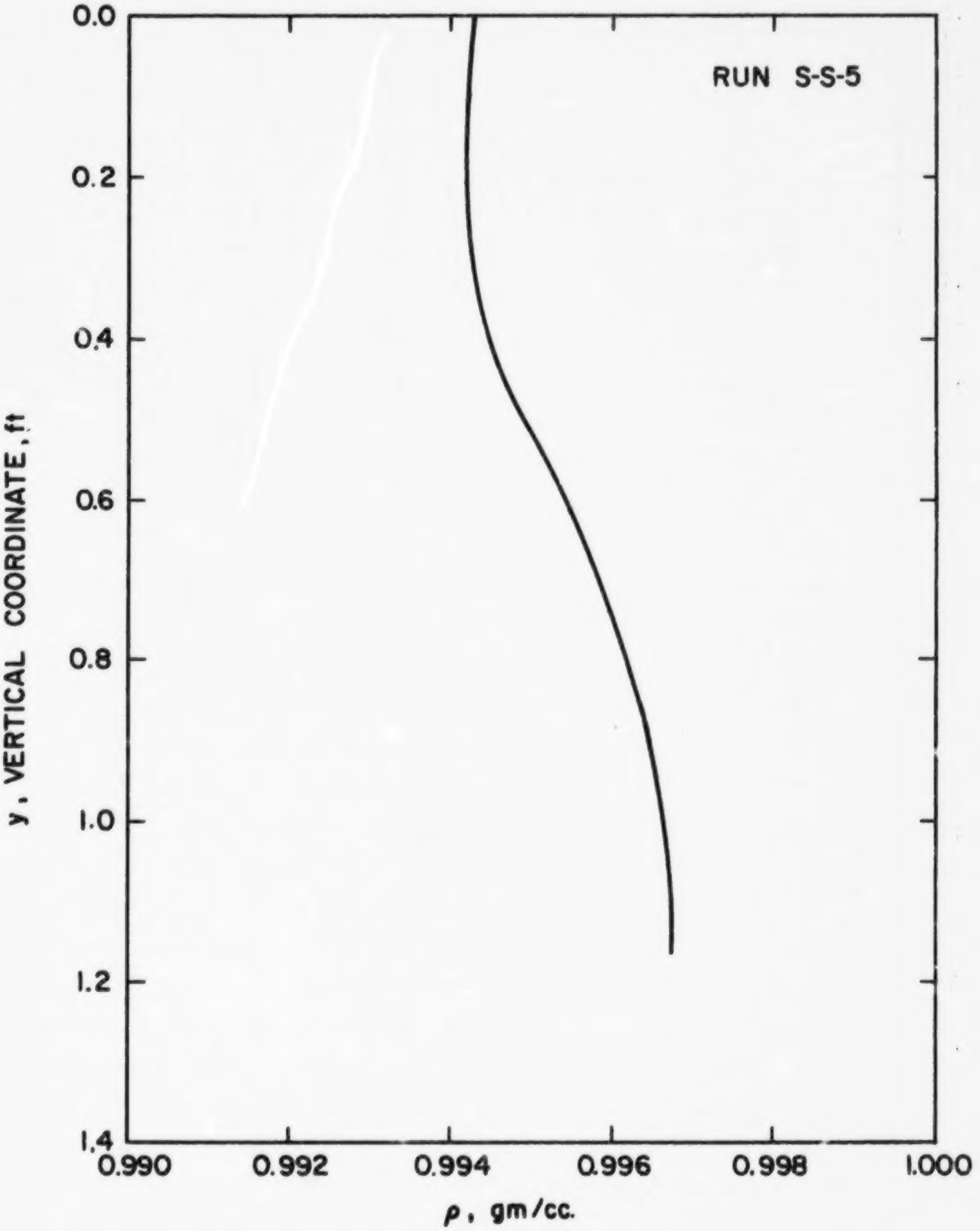


Figure 4.3.1.3a Ambient density stratification for Run S-S-5

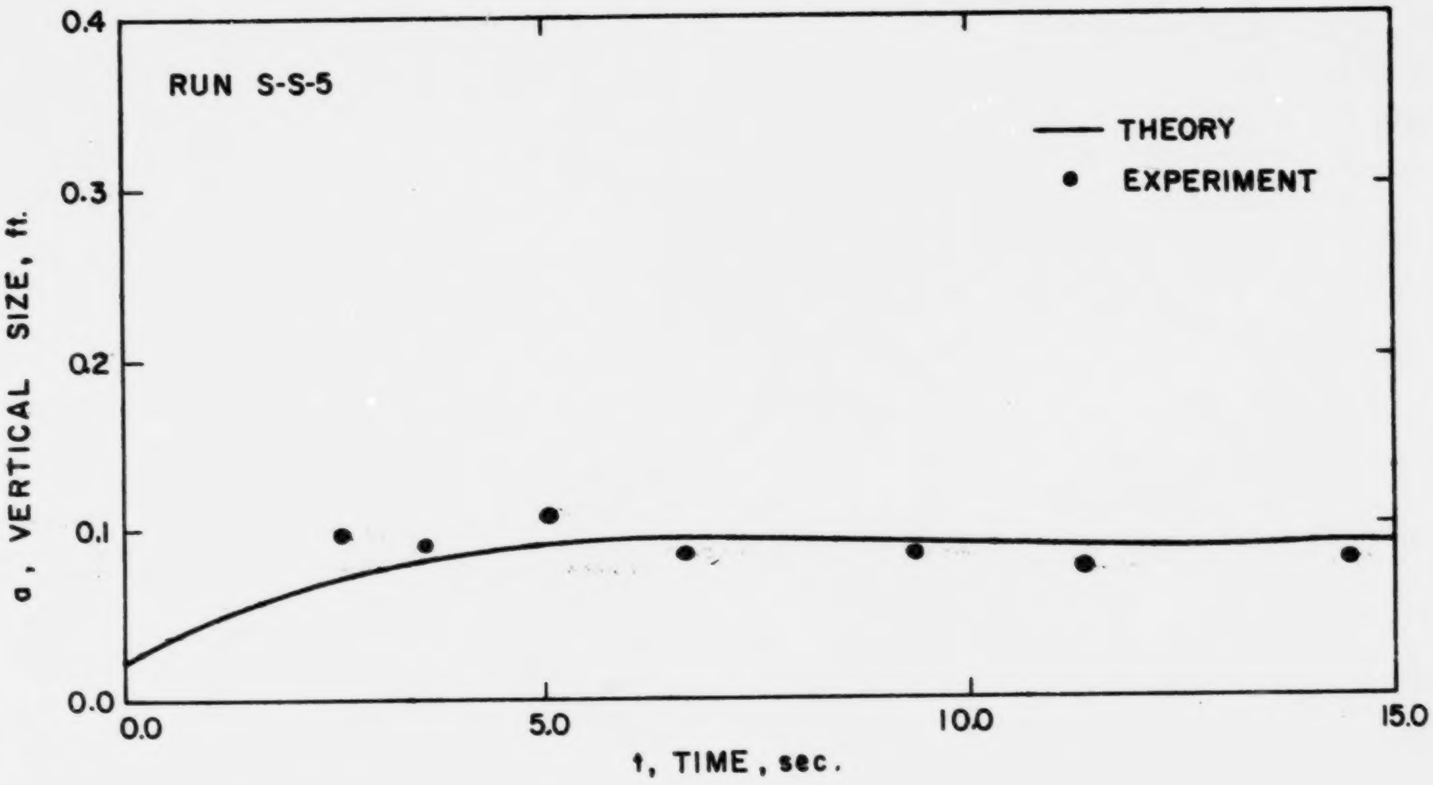


Figure 4.3.1.3b Comparison of experiment with numerical model (Run S-S-5)

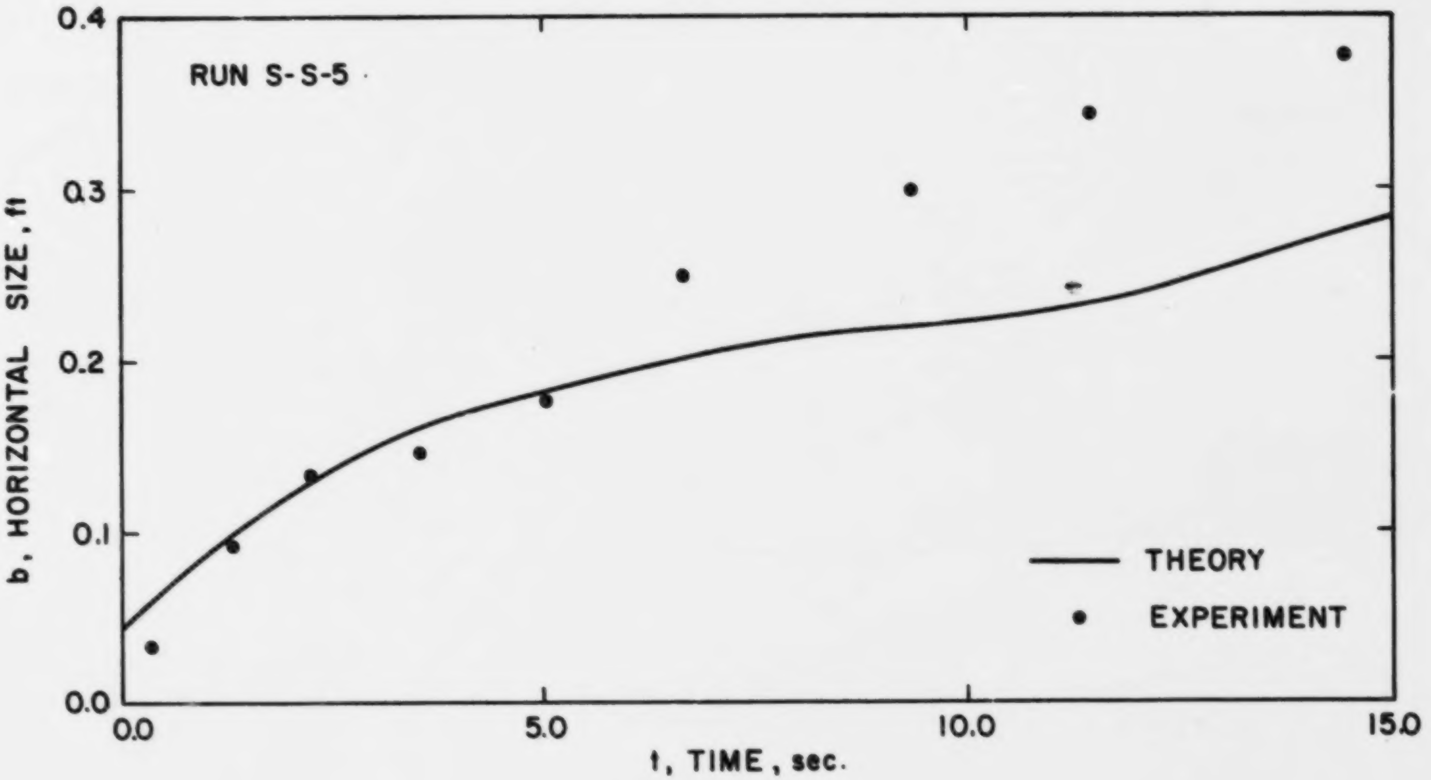


Figure 4.3.1.3c Comparison of experiment with numerical model (Run S-S-5)

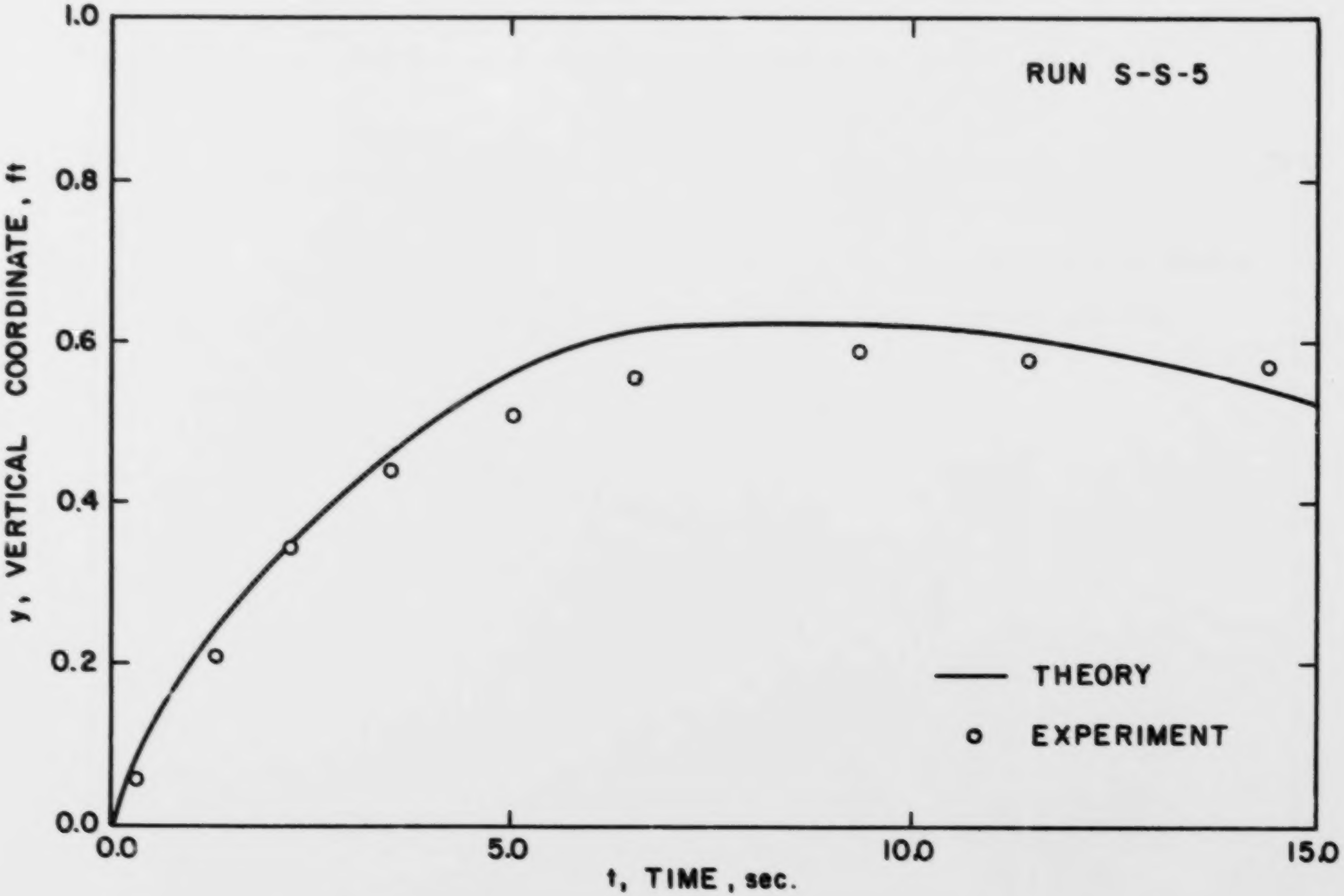


Figure 4.3.1.3d Comparison of experiment with numerical model (Run S-S-5)

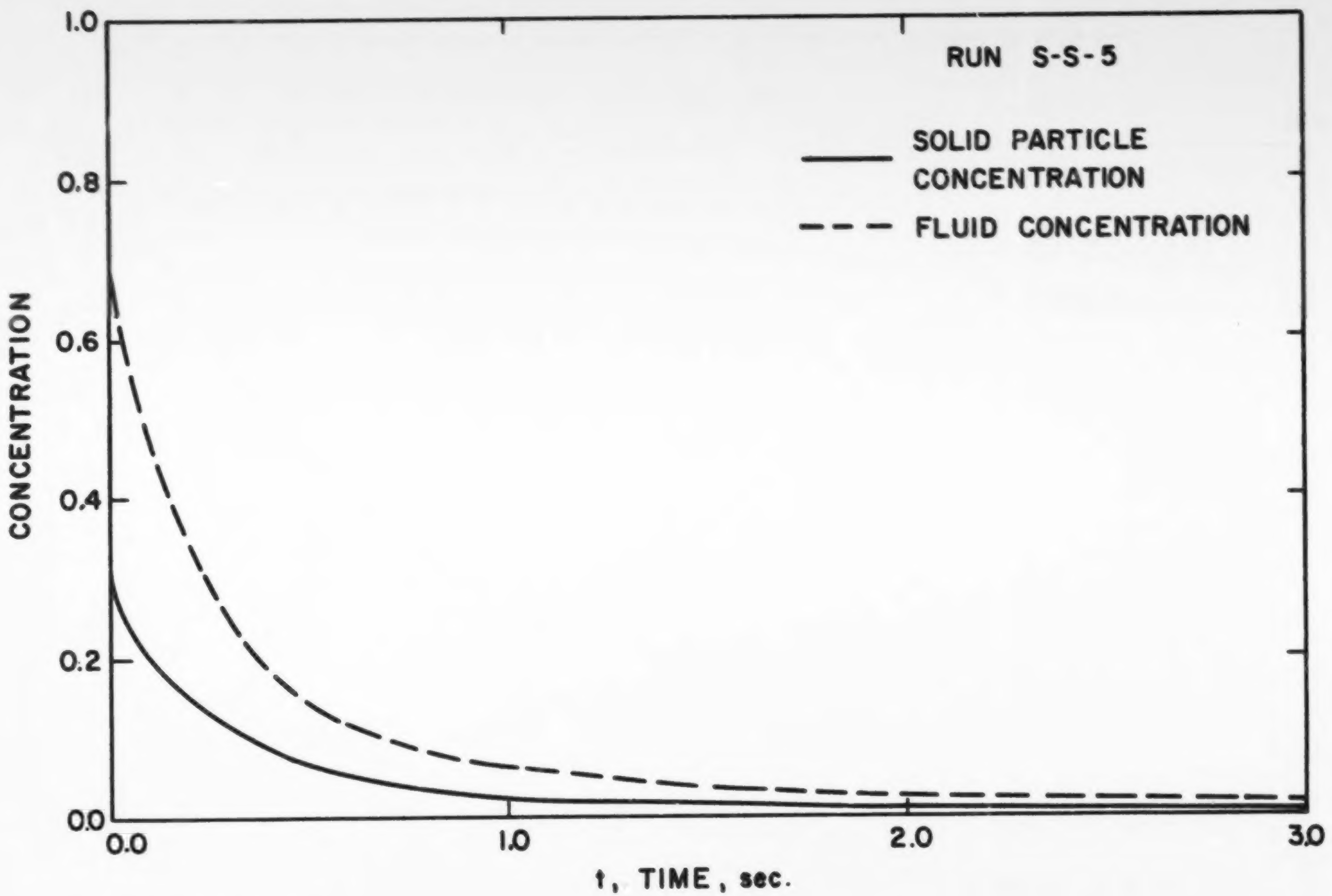


Figure 4.3.1.3e Waste concentrations from numerical model (Run S-S-5)

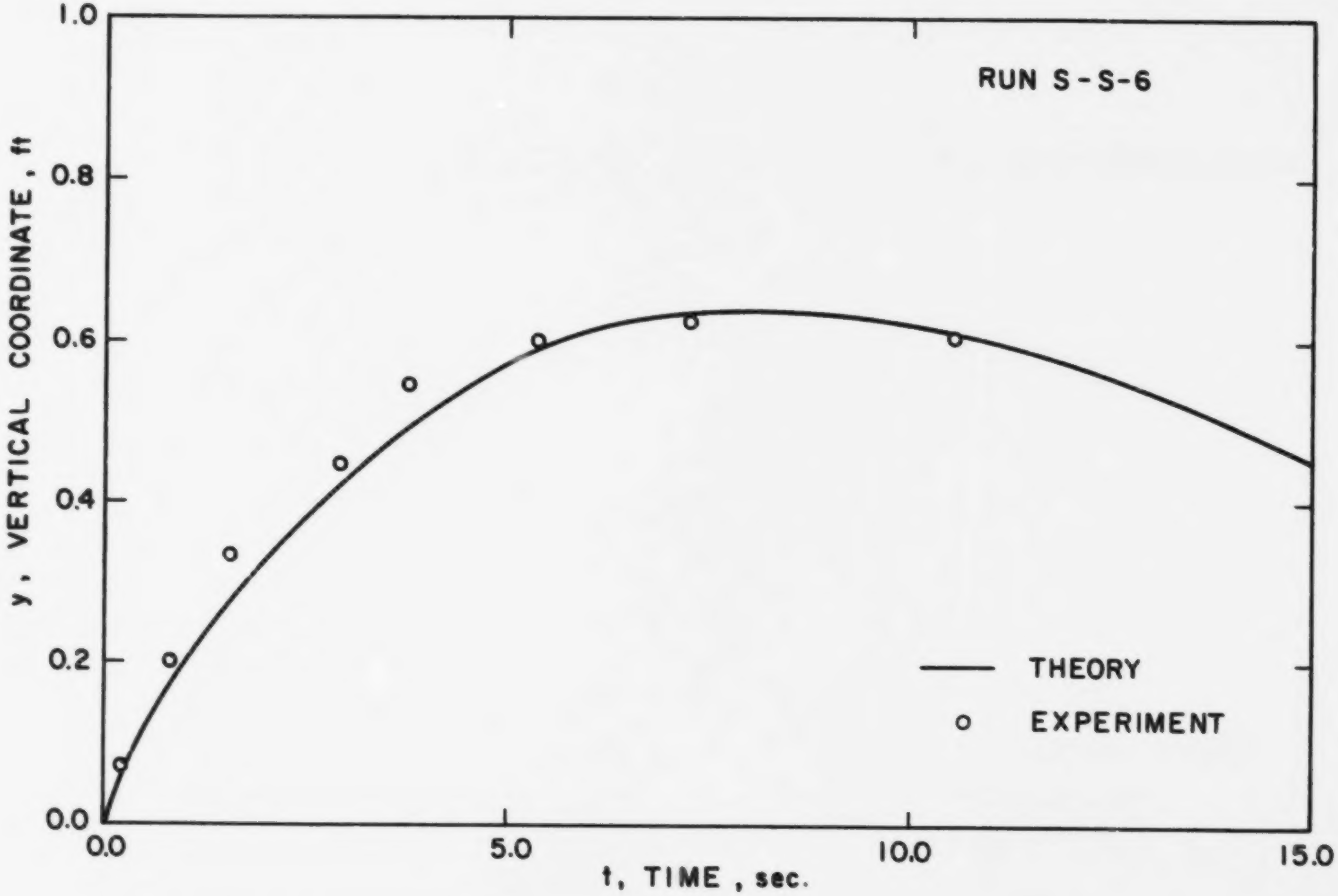


Figure 4.3.1.4 Comparison of experiment with numerical model (Run S-S-6)

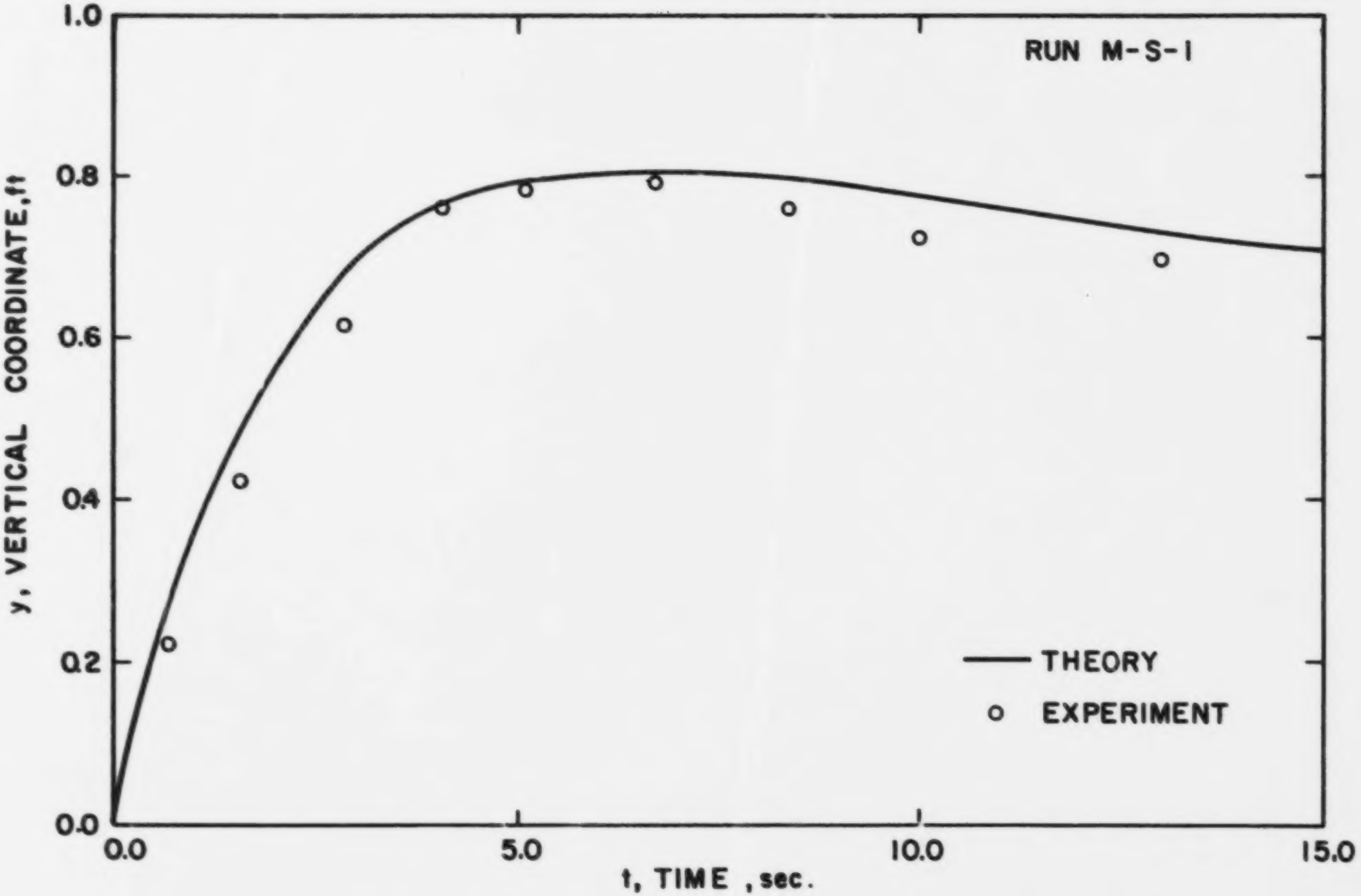


Figure 4.3.1.5 Comparison of experiment with numerical model (Run M-S-1)

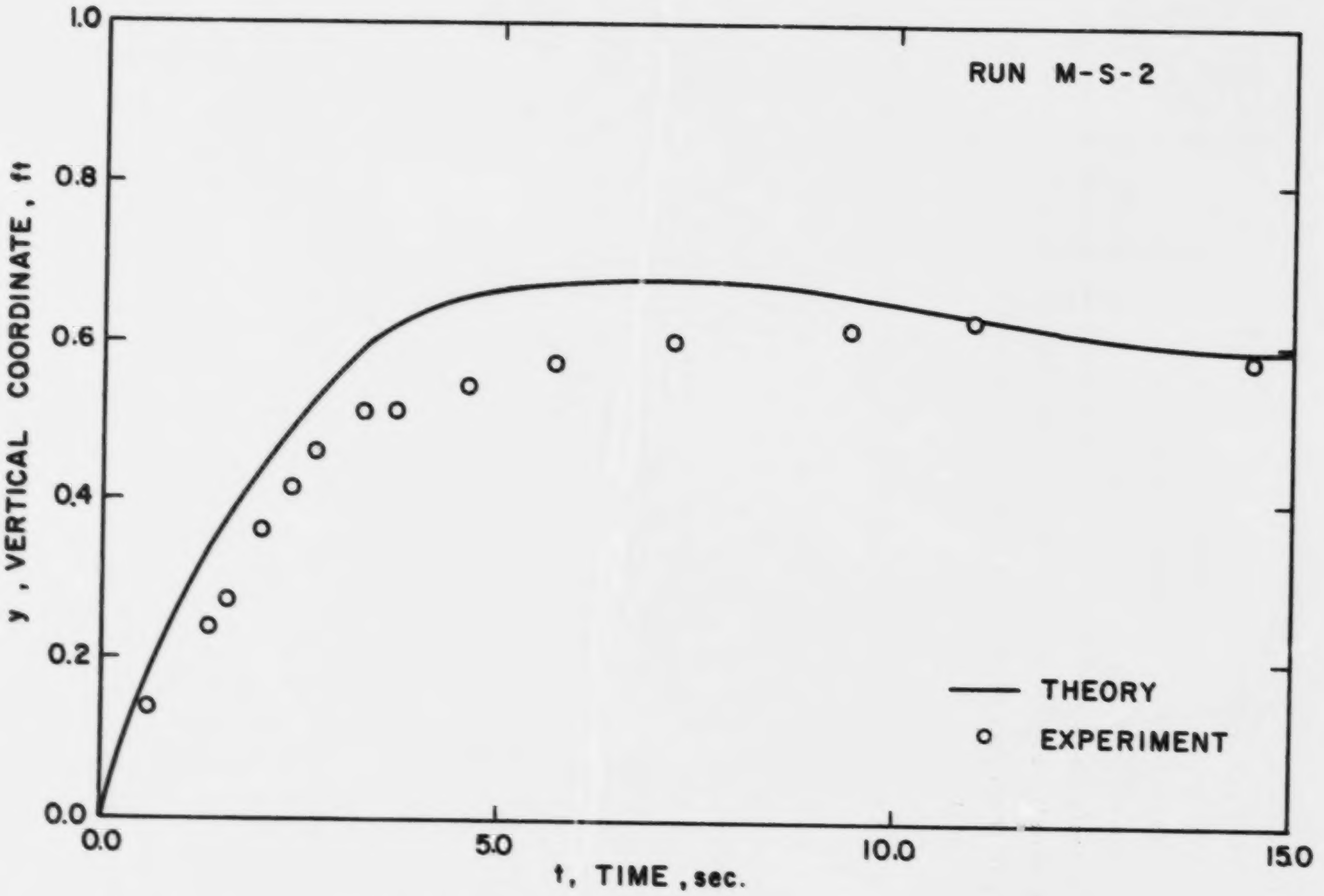


Figure 4.3.1.6 Comparison of experiment with numerical model (Run M-S-2)

It is interesting to note that dirty thermals were never found in the runs with stratified ambient. This could be explained in terms of the stability in the flow field. In the uniform density runs, the density of the cloud is always larger than the ambient, hence it is always unstable, and a deviation of the cloud shape caused by the initial injection tends to be magnified by the unstable condition. However, in a stratified ambient, when the cloud penetrates the neutrally buoyant position, the stability condition changes from that of unstable to stable, and any deviation in shape tends to be restored.

4.3.2 Continuous Discharge From a Horizontal Travelling Vertical Jet

Tables 4.1b and 2b summarize the experiments simulating Barge Operation 2 involving a jet type discharge. Selected detailed experimental results are shown in Figures 4.3.2.1-8 where the predictions based on the mathematical model are also shown. It is readily observed that the comparison between the model and the experiments is very good.

Two different materials were used in the experiments, namely salt water and sewage sludge. Experiments with a salt water jet in a uniform density were used to test the adequacy of the mathematical model in the simplest situation. Salt water jet in a stratified ambient was used to delineate the influence of the density stratification on the behavior of the jet. The experiments using sewage sludge were employed to verify the compatibility of the model for handling both the ambient density stratification and the settling of solid particles.

In the experiments performed the velocity ratio of the jet to the cross current ranges from 3.6 up to 24.64, while the densimetric Froude number varies from 2.6 up to 1840.

The experiments simulating Barge Operations 1 and 2 will be further discussed and used to verify the mathematical models in Section 5.

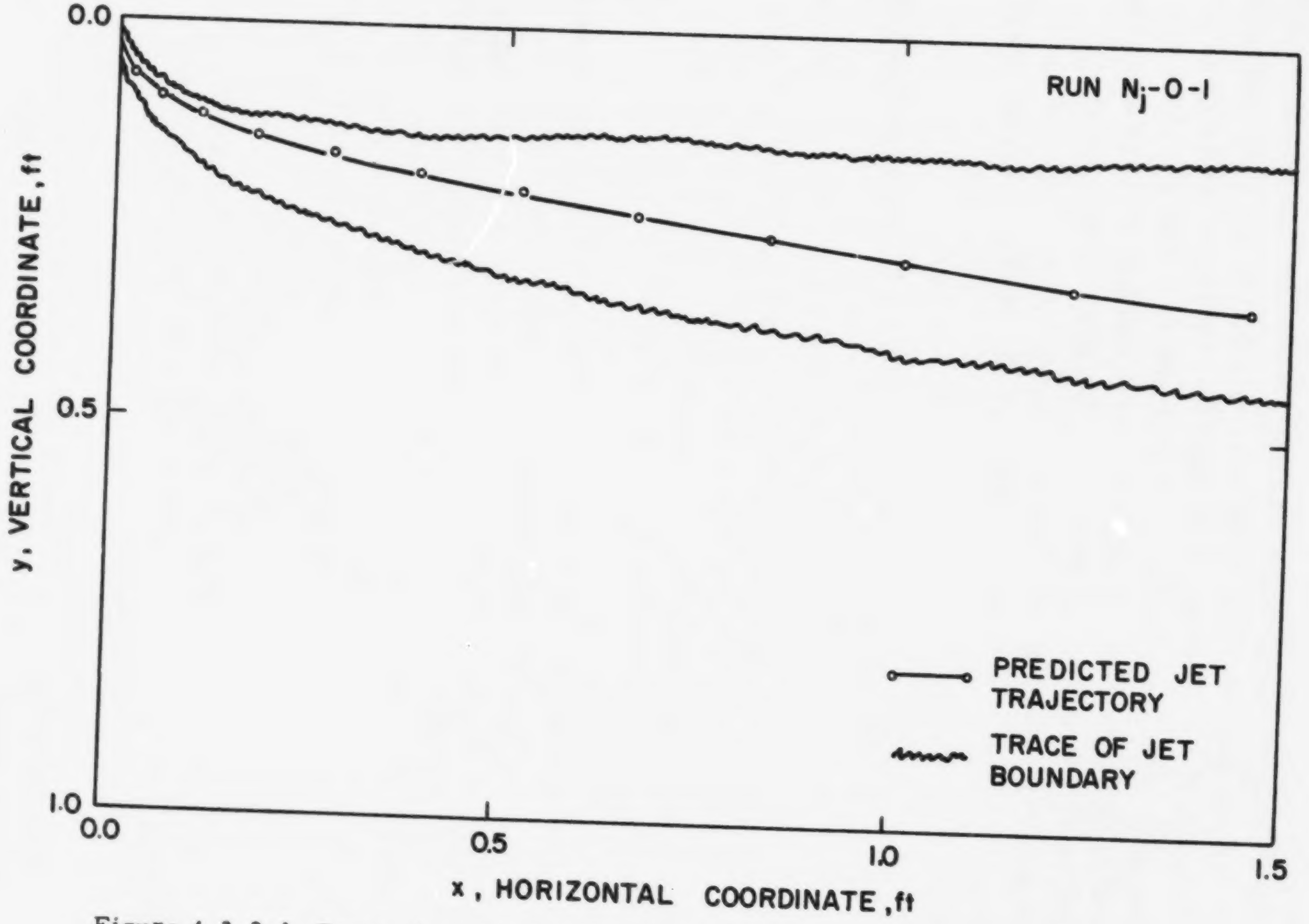


Figure 4.3.2.1 Comparison of experiment with numerical model (Run N_j-O-1)

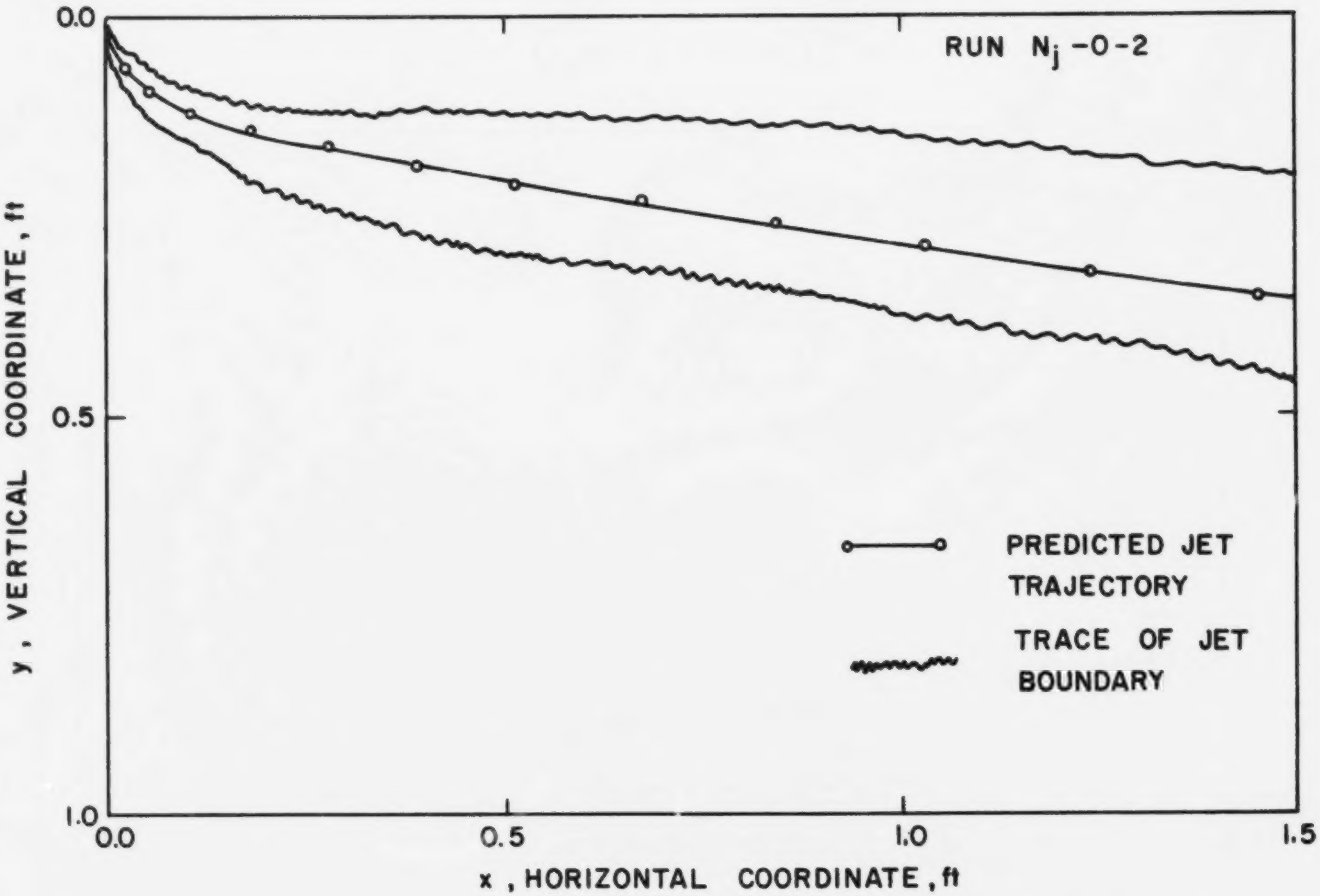


Figure 4.3.2.2 Comparison of experiment with numerical model (Run N_j-O-2)

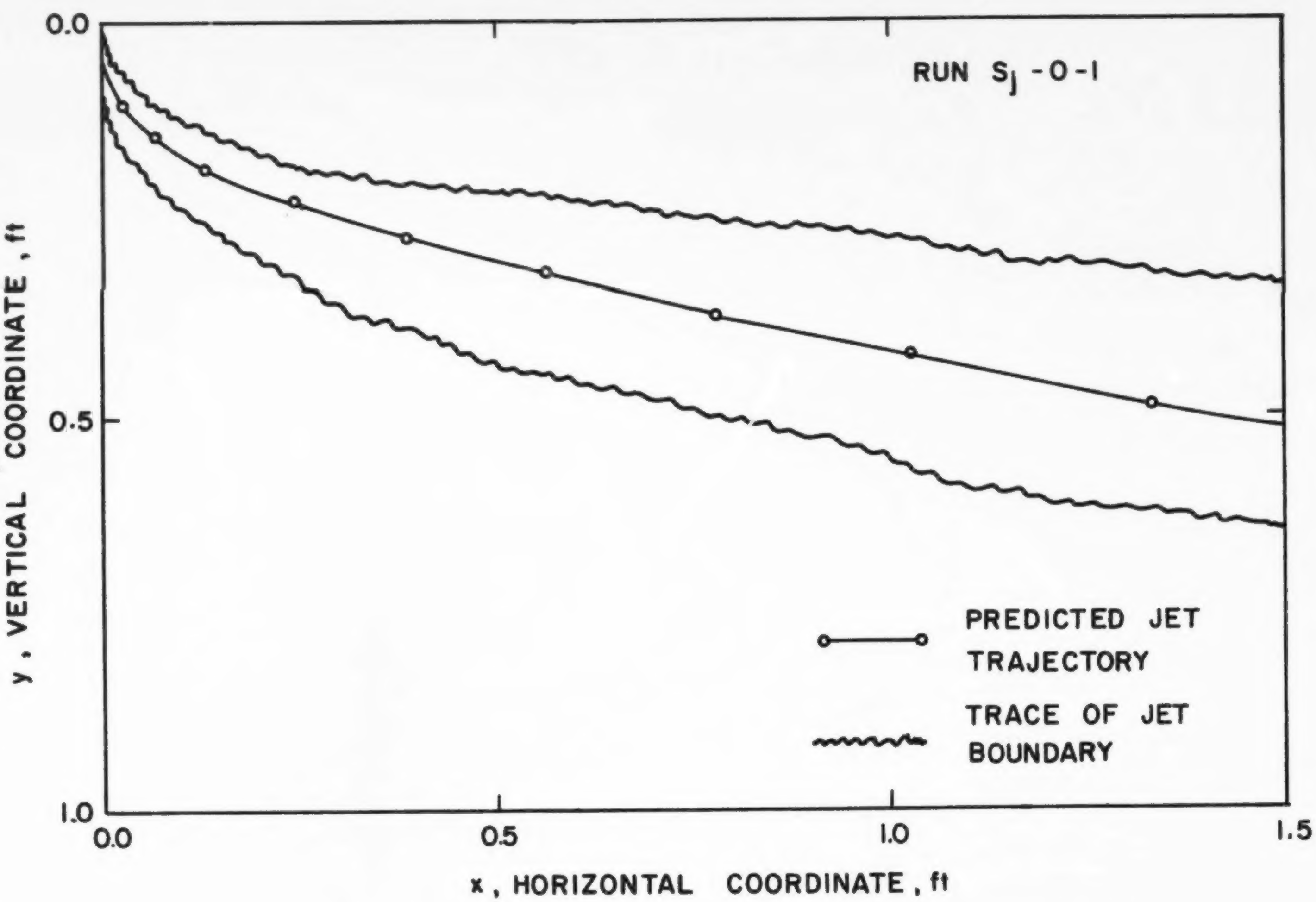


Figure 4.3.2.3 Comparison of experiment with numerical model (Run S_j-O-1)

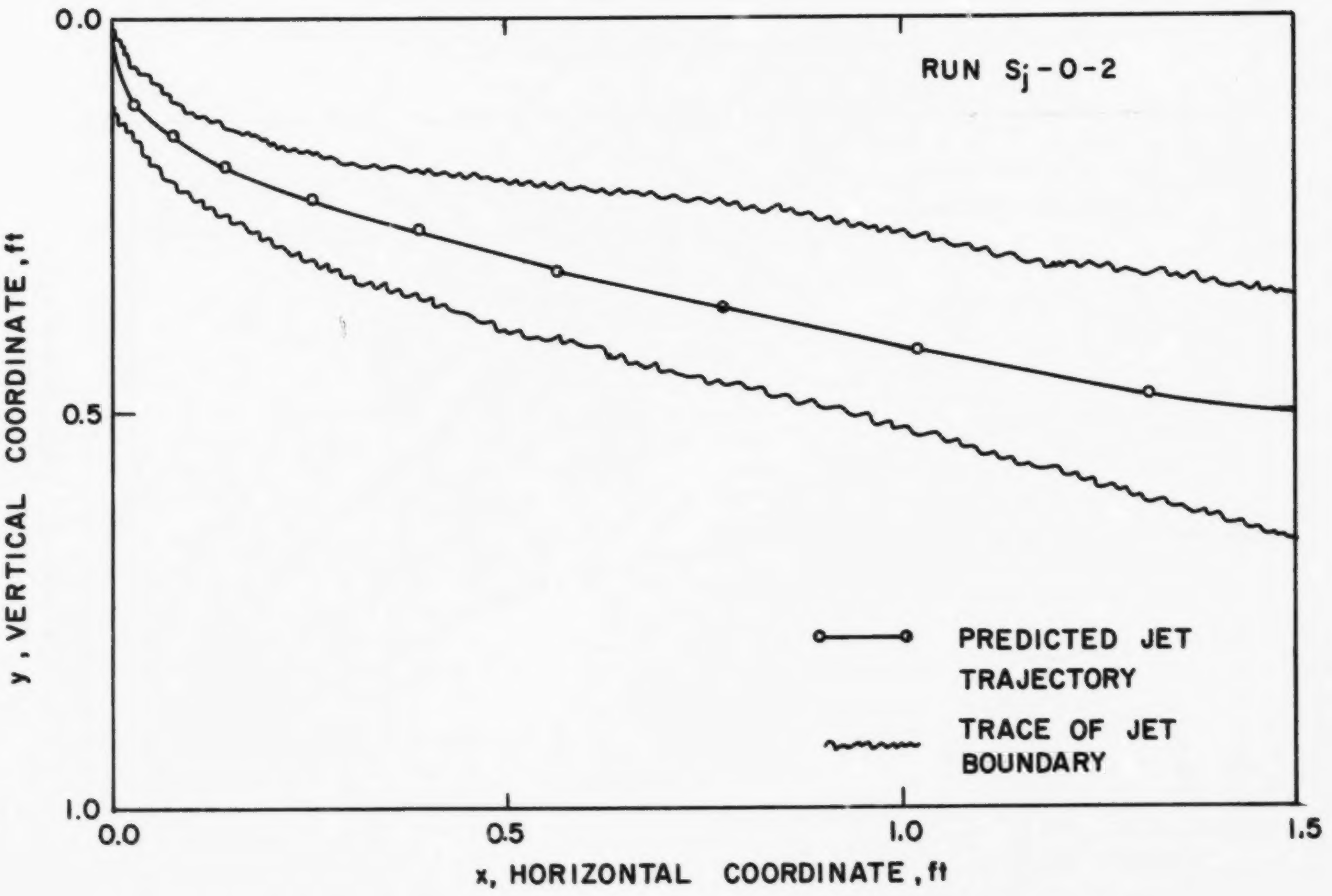


Figure 4.3.2.4 Comparison of experiment with numerical model (Run S_j-O-2)

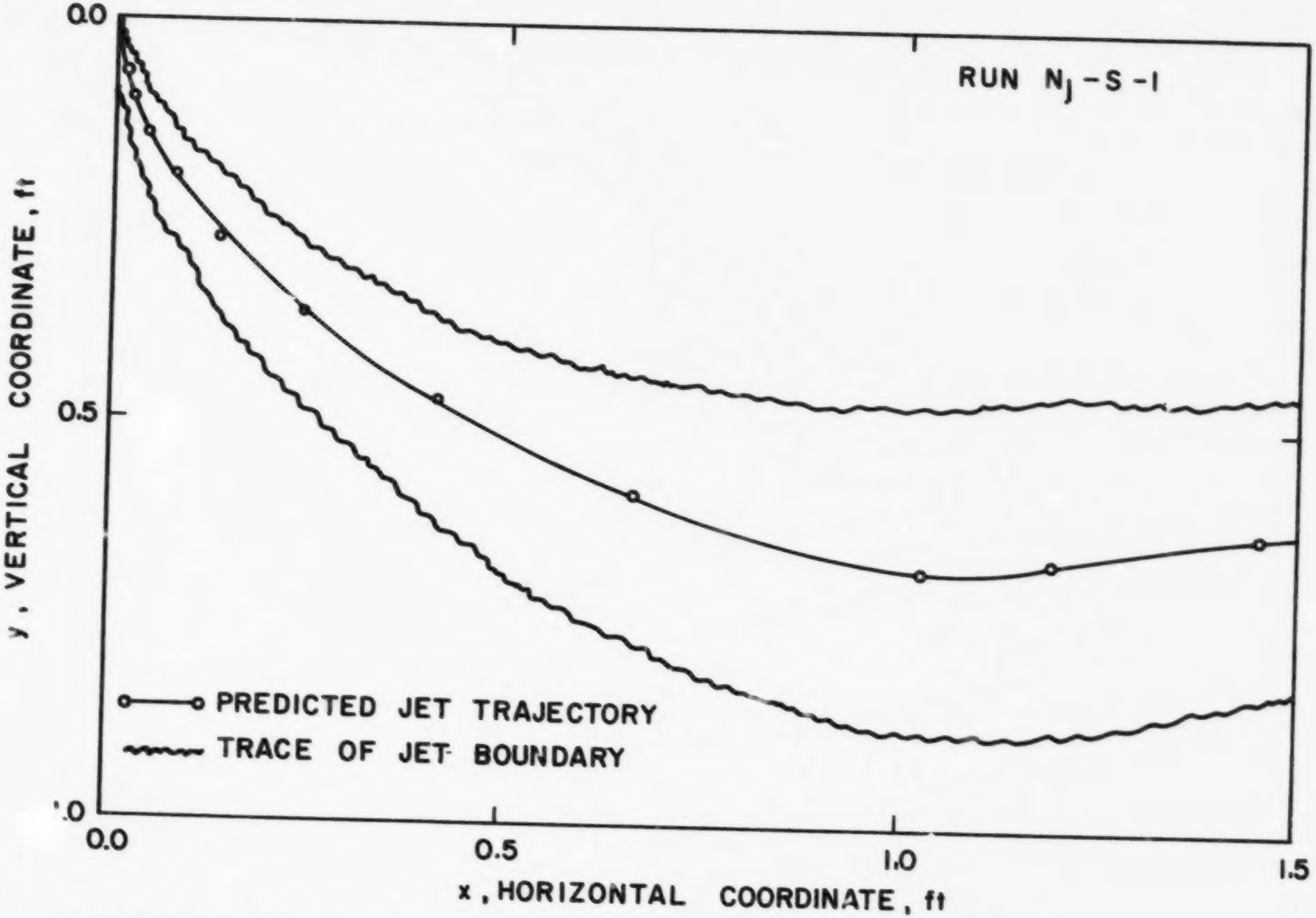


Figure 4. 3. 2. 5 Comparison of experiment with numerical model (Run N_j-S-1)

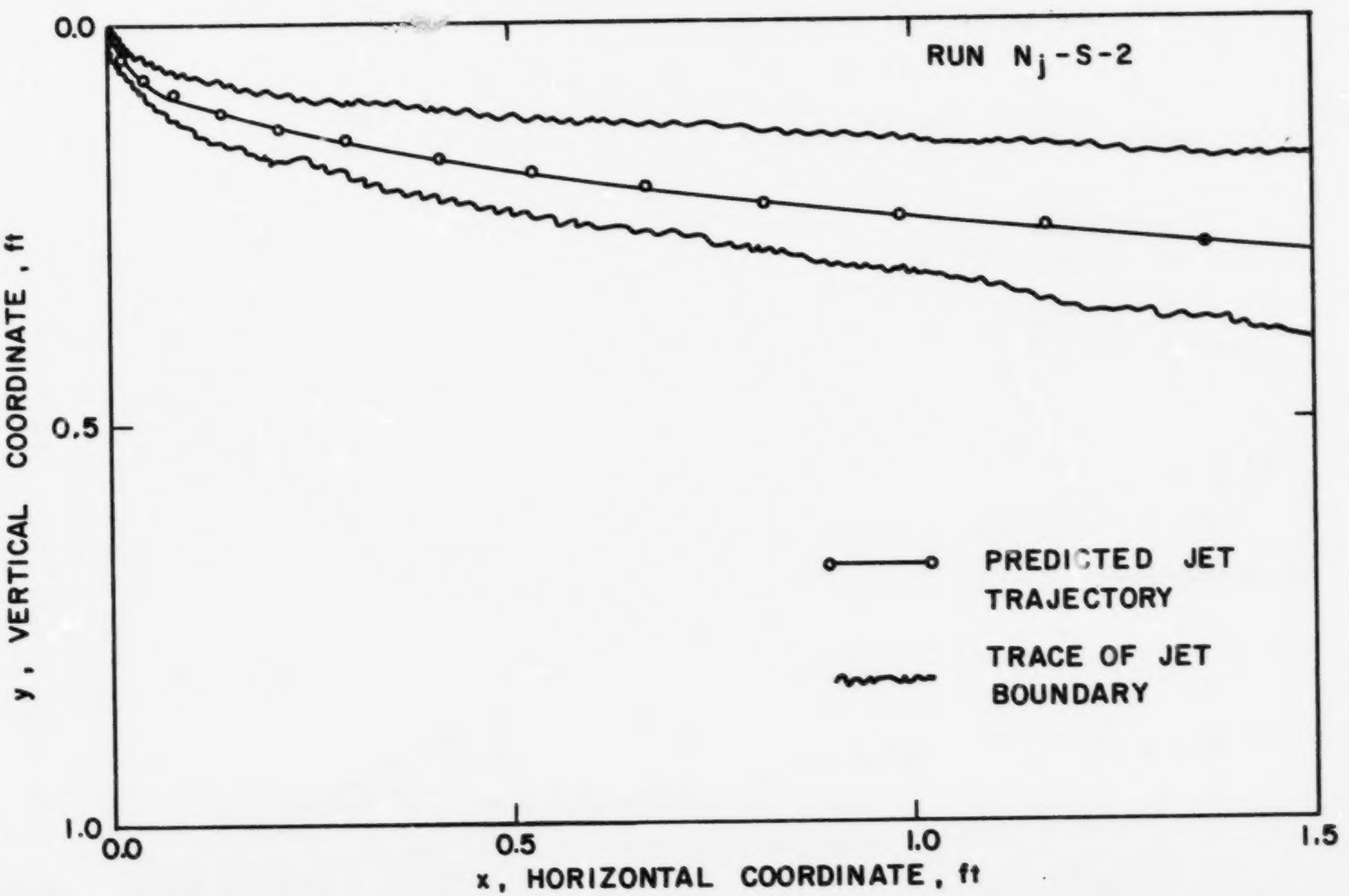


Figure 4.3.2.6 Comparison of experiment with numerical model (Run N_j-S-2)

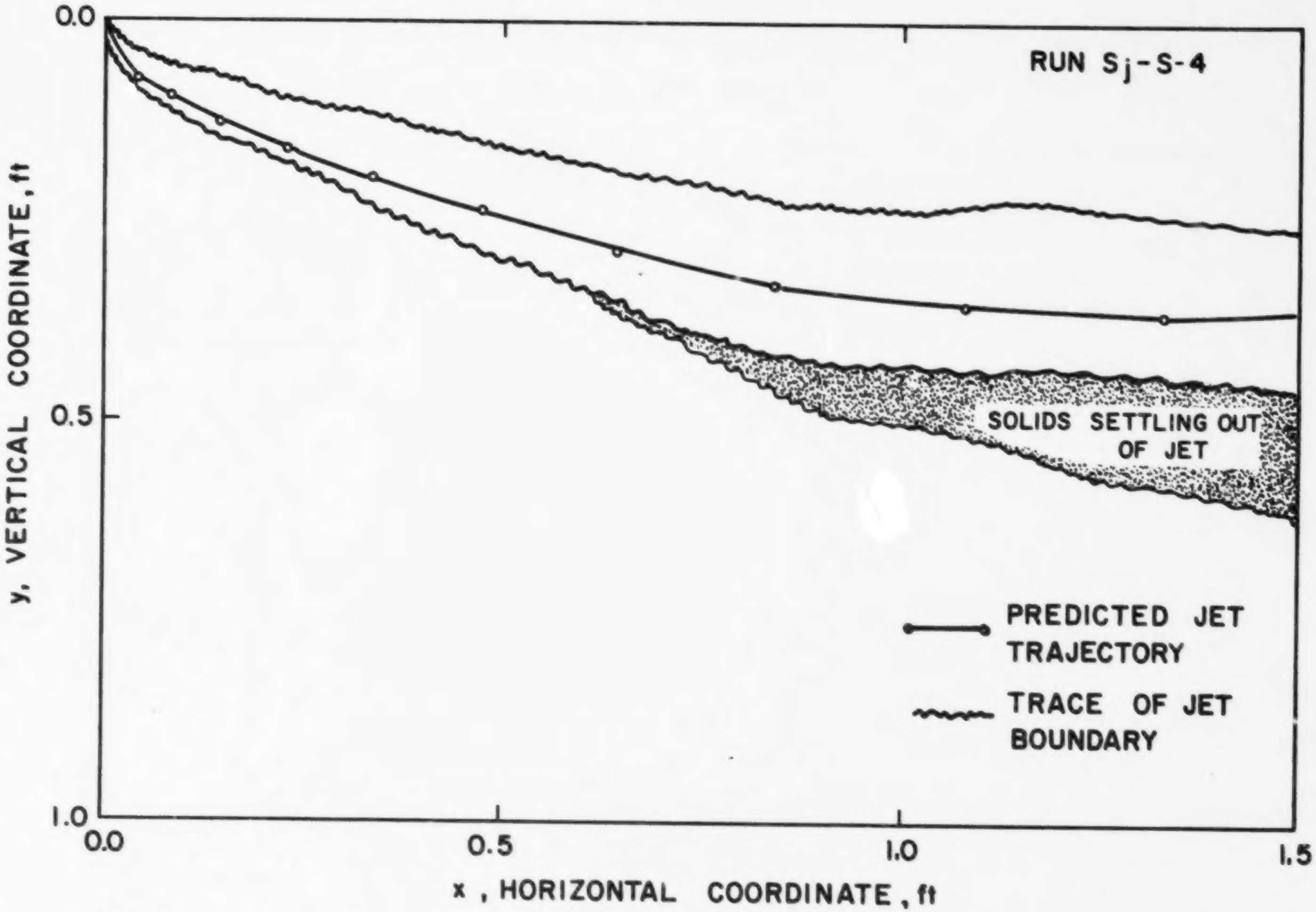


Figure 4.3.2.7 Comparison of experiment with numerical model (Run S_j-S-4)

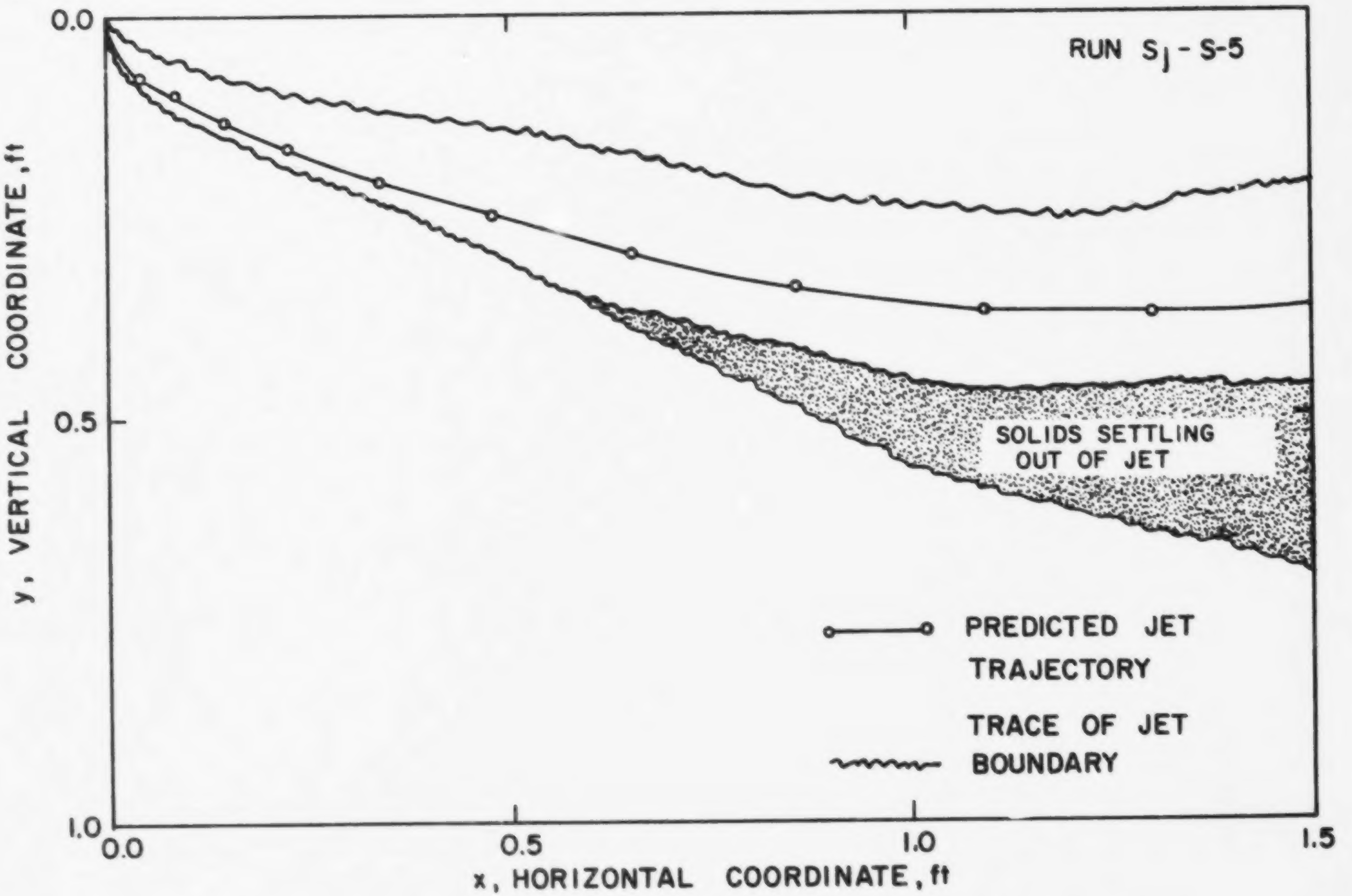


Figure 4.3.2.8 Comparison of experiment with numerical model (Run S_j-S-5)

4.3.3 Instantaneous Release of Two-Dimensional Puff

Tables 4.1c and 2c summarize the pertinent parameters and density stratifications for experiments involving the instantaneous release of a two-dimensional puff. The entrainment coefficient evaluated from the experiments in a uniform ambient was found to be close to 0.3536 as found by Richards (1965) who used salt water in a uniform ambient. Again these runs also showed the general characteristics of entrainment, convective descent, and collapse of the two-dimensional puff as postulated in the mathematical model.

SECTION V

COMPARISON OF EXPERIMENTS WITH THE MATHEMATICAL MODEL

In this section the predictions based on the mathematical model developed in Section III will be compared with the results of the experiments reported in Section IV. In the following, comparison will be made for Barge Operations 1 and 2. The three experiments performed for the two-dimensional thermal were exploratory in nature and no comparison will be made herein.

5.1 Barge Operation 1

In the comparison, the initial velocity, volume, gross density of the discharge and density stratifications obtained directly from experimental data are used in the numerical simulation. The fall velocity of the particles was estimated by putting a small amount of very dilute waste material in the tank and timing the time needed for the particles to pass a fixed distance. For the mud and sewage sludge the fall velocities are found to be less than 0.005 fps and 0.02 fps respectively. The density and concentration of the solids are estimated. For the various coefficients needed for the numerical simulation, the Tetra Tech suggested values are used except for the entrainment coefficient which is allowed to vary for different experiments and the best fit value is chosen. The best fit entrainment coefficients for the stratified ambient runs are presented in Table 4.1a and are found to be between 0.21 and 0.265.

All the experiments with stratified ambient listed in Table 4.1a have been compared with the mathematical predictions. However, to avoid excessive repitition only six selected runs are presented in Figures 4.3.1.1-6. All other runs compare at least as well as those selected. The positions of the centroid of the waste cloud are plotted vs. time and presented for all the runs selected. Further information such as ambient density stratification, gross size and variation of concentration inside the cloud are shown only for RUN S-S-5.

In Figures 4.3.1.1-6, the waste clouds are seen to descend and then oscillate about a neutrally buoyant position. The comparisons between the experiments and the theory are found to be fairly good. Note that in spite of some uncertainty in the values of some of the coefficients, it seems that the positions of the cloud can be predicted with good accuracy by only varying the entrainment coefficient between 0.21 and 0.265 in the present investigation.

Figure 4.3.1.3a shows a typical ambient density stratification used in the Experiments.

In Figures 4.3.1.3b and 4.3.1.3c, the gross size of a sewage sludge cloud is compared with the numerical simulation. The comparison for a , the vertical size, is good. However, the experimentally obtained horizontal size b is larger than the theoretical prediction beyond a certain time. Since the experiments were performed in a 9 inch wide tank, the discrepancy in the prediction of b is believed to be from the influence of the limited width. The presence of the walls forced the cloud to spread more in the other directions which led to the apparent excess expansion observed in the experiment. Note that salt water was used in the experiments for RUNS N-S-1 and N-S-2. No significant difference was observed between these runs and those with solid particles in the cloud except for the phenomenon of settling.

Figure 4.3.1.3e shows the fluid and solid concentrations in the cloud as predicted by the mathematical model for RUN S-S-5. The concentrations are seen to decline very rapidly in the early stage of convection due to entrainment. This rapid decline of the solid concentration suggests that the phenomenon of hindered settling would not be of major concern in the selection of the settling coefficient θ_{ij} as discussed in Section 3.2.1. No experimental data is obtained on the concentrations. However, since the size of the cloud is directly related to the concentration during convection when settling was minor, the favorable comparison on the position and size between prediction and experiment indicates that the model is adequate.

From general observations of both the numerical simulation and the experimental data, it is found that the initial gross density and velocity of the waste cloud play important roles in the convection phase. For a waste cloud with high density, the initial velocity is of less importance. However, if the gross density is nearly the same as the ambient density, then the influence of the initial velocity dominates.

In the numerical simulation for comparison with the experiments the density and concentration of the solid particles were estimated. However, it was found that changes of the inputs for solid density and concentration over a factor of two did not change the results significantly. The reason is that the fall velocities are very small for the mud and digested sewage sludge used in the experiments. The mechanics is affected much more by the dilution and entrainment than by settling in the whole period of convection and collapse. Hence the gross density is made more important rather than the solid density and concentration. However, regarding the final phase of long term diffusion of the waste material, accurate information on the concentration would be needed to predict the concentration at the end of dynamic collapse for input to the long term diffusion model.

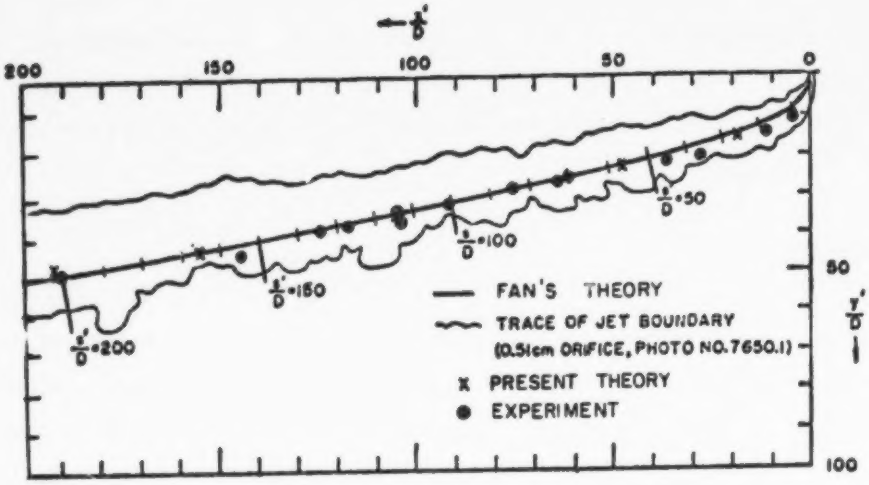
5.2 Barge Operation 2

In the comparison between predictions and experiments for Barge Operation 2, the jet discharge characteristics and ambient conditions used in the predictive model are those measured in the experiments. The empirical coefficients used are those built into the program. The concentration and density of the solid particles in the discharge were estimated based on gross measurements. For comparison, the centerline trajectories of the jet obtained by numerical simulation are plotted against experimental data of the jet boundaries. Although all runs were compared, only eight representative runs are selected and presented in Figures 4.3.2.1 to 4.3.2.8 to avoid excessive repetition.

For showing the influence of the ambient density and solid particles on the gross behavior of the jet, the data will be presented in the order of N_j-0, S_j-0, N_j-S and S_j-S successively. The designations are for salt water jet (N_j) and sewage sludge jet (S_j) in a homogeneous density (0) or density stratified (S) cross current respectively. The results of the first group are shown in Figures 4.3.2.1-2. The jet is seen to bend over in the direction of the cross current and it tends to reach the bottom. Figures 4.3.2.3-4 show that the solid particles inside the sewage sludge jet do not change the jet behavior significantly. The effects of density stratification on the salt water jet are shown in Figures 4.3.2.5-6. Figure 4.3.2.5 shows that the salt water jet is trapped in a neutrally buoyant position; the jet first overshoots the neutrally buoyant position; however, it is forced back by the density stratification. Figure 4.3.2.6 does not show the influence of the density stratification since the jet has not reached the position of strong density gradient yet. Figures 4.3.2.7-8 show clearly that the main core of the jet is trapped in a neutrally buoyant position while particles are settling out of the jet as shown in the figures.

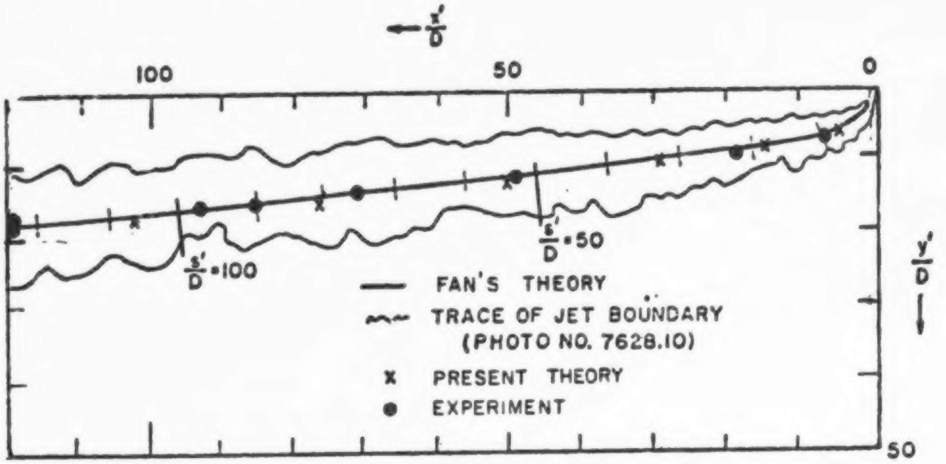
For another check, two runs were made to compare with Fan's (1967) experimental data and theoretical predictions. The comparisons are found to be very good as shown in Figure 5.1.

From the comparisons of numerical simulation to the experimental data it is found that the jets with or without solid particles behave closely to what is assumed in the formulations. In the experiments, the development of horse-shoe profiles as found by other investigators were observed; however, the assumption of top-hat profiles appears adequate to provide useful predictions. Hayashi (1971) reported that a bent-over plume splits sideways into two concentrated regions with a clear space between them when the upward injected plume comes close to the free surface. This phenomenon was not observed when the jet plume was trapped in a neutrally buoyant position in a density stratified ambient in the present investigation. The



F=20 k=8

a)



b) F=20 k=4

Figure 5.1 Comparison of present theory with Fan's experiments (from Fan (1967))

free surface can be considered as a position with an infinite density gradient and perhaps if the density stratification is sufficiently strong in the ambient the phenomenon of splitting a plume into two separated regions may occur.

5.3 Discussion

From the above comparisons, it can be concluded that the mathematical model developed is able to provide good estimates on the behavior of wastes discharged from barges. Perhaps the most important verification which can be inferred from these experiments is that the general behavior of the buoyant (or sinking) elements and jets are not materially affected if at all by the presence of solid particles of the type encountered in typical wastes (those with relatively small settling velocities).

SECTION VI

EXAMPLE SOLUTIONS

The computer program based on the mathematical model developed in Section III has been used to obtain the dispersion characteristics in a variety of cases. These will be presented in this section.

Before the computer program can be used, it is first necessary to specify a) the ambient conditions, including the currents, diffusion coefficients, and density stratification, b) the waste characteristics, including the density, size, and solid characteristics, c) the discharge method and other control parameters, and d) the various numerical coefficients. Examination of the list of inputs presented in Appendix A reveals that a great number of parameters are needed for the complete specification of each case. A parametric study based on this model, although highly desirable, would entail a very large number of cases and is beyond the scope of the present investigation. While a parametric study should be performed in the future, in the following, only representative cases are presented to a) test the model and program and b) delineate the effects of some of the more important parameters.

Tables 6.1, 6.2, and 6.3 summarize the parameters used in the various example runs for Barge Operation 1, 2, and 3 respectively.

The computations for most of the cases are terminated at the conclusion of the dynamic collapse phase. A few representative cases are selected from the tables for which the computations are allowed to proceed further into the long term diffusion phase.

The run designations used for identification consist of three entries, e.g. D-S-6. The first letter signifies the barge operation (D for bottom opening hopper dump, J for jet discharge, and W for discharge into the barge

TABLE 6.1

SUMMARY OF PARAMETERS OF RUNS MADE FOR BARGE OPERATION 1

RUN NO.	ρ_{a1}	Remarks
D-L-1	1.030	
D-L-2	1.029	
D-L-3	1.028	
D-L-4	1.027	
D-L-5	1.026	
D-L-6	1.025	
D-L-7	1.024	
D-L-8	1.0235	
D-L-9	1.024	UA0=1
D-L-10*	1.024	UA0=1, WA0=1
D-L-11	1.030	U(1)=1, W(1)=1
D-S-1	1.028	
D-S-2	1.027	
D-S-3*	1.026	
D-S-4	1.025	
D-S-5	1.024	
D-S-6	1.0235	
D-S-7	1.024	UA0=1
D-S-8	1.024	UA0=1, WA0=1
D-S-9	1.026	V(1)=0
D-S-10	1.026	V(1)=5
D-S-11	1.026	V(1)=5, H=65
D-S-12	1.026	RB=10
D-S-13	1.024	FI=10
D-S-14	1.024	FI=1

Table 6.1 (continued)

RUN NO.	ρ_{a1}	Remarks
D-S-15	1.024	FRICTN=0.5
D-S-16	1.024	FRICTN=0.
D-S-17	1.026	CFRIC=0.01
D-S-18	1.026	ALPHAC=0.1
D-S-19	1.026	ALPHAC=0.
D-LL-1*	1.023	V(1)=0.6 Collapse phase bypassed
D-F-1	1.0231	V(1)=0.6
D-FS-1*		UA0=1, Y(F)=0, 20, 40, 100, ROA(I)=1.02, 1.02, 1.03, 1.035, YK1=18, YK2=22, YK3=38, YK4=42, YU=20, YW=20, YE=40
D-FS-2*		Same as D-FS-1 except GAMA1=0.02
D-2S-1		UA0=1, YU=30, YW=40, YE=50, ROA(I)=1.023, 1.023, 1.024, 1.0245

---

* Calculations carried to long term diffusion phase.

TABLE 6.2

SUMMARY OF PARAMETERS OF RUNS MADE FOR BARGE OPERATION 2

RUN NO.	ρ_{ai}	Remarks
J-L-1	1.024	
J-L-2	1.0235	
J-L-3	1.0231	
J-L-4	1.024	UA0=1
J-L-5	1.024	UA0=1, WA0=1
J-S-1	1.024	
J-S-2	1.0235	
J-S-3	1.0231	Collapse phase bypassed
J-S-4	1.0230	
J-S-5	1.024	UA0=1
J-S-6*	1.024	UA0=WA0=1
J-S-7	1.0235	BC(1)=1
J-S-8	1.0235	U(1)=10
J-S-9	1.0235	CY(1)=20
J-S-10	1.0235	UB=5
J-S-11	1.0235	THETA2(1)=45
J-S-12	1.02311	
J-F-1	1.024	SAI=225
J-F-2	1.024	SAI=225, UA0=1, WA0=1
J-2S-1	1.024	UA0=1, YU=30, YW=40, YE=50, UB=5
J-4S-1	1.024	UA0=1, WA0=1

* Calculations carried to long term diffusion phase

TABLE 6.3

SUMMARY OF PARAMETERS OF RUNS MADE FOR BARGE OPERATION 3

RUN NO.	ρ_{al}	Remarks
W-L-1	1.0232	
W-L-2	1.0230	
W-L-3	1.0232	BB=10
W-L-4	1.0232	QD=100
W-L-5	1.0232	UB=5
W-S-1	1.0232	
W-S-2*	1.0230	
W-4S-1	1.0232	UB=5

* Calculations carried to long term diffusion phase

wake). The second letter signifies the solid whose characteristics are listed in Table 6.4. The last number is simply a numerical sequence within each group.

i) Ambient density stratification.

The ambient density ROA(I) is specified by four points at depths Y(I) taken to be 0., 40., 60., and 100 feet. The density at the surface and 40 foot depth is 1.023 gm/cc. The density ρ_{a1} at 60 and 100 feet varies from 1.023 to 1.030 for different runs. The value of ρ_{a1} is indicated in the tables. For some runs, a density gradient is inserted between 60 and 100 feet. In such cases, ROA(I) is provided in the tables. A few runs also use different values for Y(I). These are also indicated in the tables.

ii) Ambient currents. (see Figure 3.6.1)

The ambient currents are specified by the parameters YU, YE, YW, UA0, WA0. These are taken to be 50., 50., 100., 100., 0., 0., respectively unless specified otherwise in the remarks column.

iii) Vertical diffusion coefficients. (see Figure 3.6.1)

The vertical diffusion coefficient profile is specified by the parameters YK1, YK2, YK3, YK4, AKY1, AKY2, AKY3. These are taken to be 35., 45., 55., 65., 0.05, 0.005, 0.01 respectively unless specified otherwise in the remarks column.

iv) Waste characteristics

The waste characteristics are specified by its gross density ROO, and the solids characteristics. The characteristics for the various solids are summarized in Table 6.4.

TABLE 6.4

SUMMARY OF SOLID WASTE CHARACTERISTICS USED IN SIMULATION RUNS

Solid Designation	ROO (gms/cc)	CS	ROAS (gms/cc)	WS (ft/sec)
S	1.12	0.15	1.8	0.005
L	1.3	0.2	2.5	0.05
LL	1.	0.2	2.5	0.5
F	1.05	0.	---	0.
FS	1.10	0.2	1.0	-0.01
2S	1.13	0.2	0.9	-0.05
		0.1	2.5	0.05
4S	1.2	0.1	1	-0.1
		0.2	1	-0.001
		0.15	2	0.15
		0.005	2	0.0015

v) Discharge characteristics

In Barge Operation 1, the discharge characteristics are characterized by RB the radius of the waste load, and U(1), V(1), W(1), the velocity components of the waste at the point of discharge. These are taken to be 5, 0, 1, 0. respectively unless specified otherwise in the remarks column.

In Barge Operation 2, the discharge characteristics are characterized by the jet radius BC(1), discharge angle THETA2(1) with respect to the vertical, discharge velocity U(1), and discharge depth CY(1). These are taken to be 0.5, 0., 5., and 10. respectively unless specified otherwise in the remarks column.

In Barge Operation 3, the discharge characteristics are characterized by the discharge rate QD which is taken to be 10. In addition the barge width BB and barge depth DD are taken to be 25 and 10 respectively unless specified otherwise.

Moreover, in Barge Operations 2 and 3, the quantities UB, the barge velocity, SAI, the barge direction, and TIME the discharge time are needed. These are taken to be 7.5, 180°, and 500 respectively unless specified otherwise.

In all runs, built in coefficients are used except for runs D-S-13 through 19 where the deviations from the built in coefficients are noted in Table 6.1.

The graphic output from the calculations for the runs are grouped in the order given in the tables and presented in APPENDIX B. Each graph is identified by the run number. The case data are collectively presented at the beginning of the appendix before the graphs for ease of access.

The computer runs presented in the tables can be divided into three groups: 1) runs using standard inputs for solid L, 2) runs using standard inputs for solid S and 3) runs using non-standard inputs and/or other solids. Within groups 1 and 2, the only quantity which varies between runs is the ambient density stratification parameter ρ_{a1}. By comparison among these runs, the effect of ambient density stratification can be observed. By comparing runs in group 1 with the corresponding runs in group 2, the effect of solid characteristics can be seen. For the solid (L) with larger fall velocity, the waste pool sometimes reaches the bottom and then leaves the bottom when sufficient solids settle out. The effect of some of the other input parameters such as those relating to ambient currents and waste discharge characteristics can be seen by comparing runs in group 3 with corresponding runs in the first two groups. An effort has also been made to investigate the effect of the numerical coefficients. Only Barge Operation 1 is used for this purpose. Runs D-S-13 through D-S 19 are the same as run D-S-3 or D-S-5 except for one of the coefficients. The net effect of these coefficients are found to be as expected, e.g. increasing the friction coefficient F1 hastens the transition from collapse to long term diffusion while decreasing the rate of spreading due to collapse. It is believed that while the effect may be significant for each single discharge, the integrated effect for many discharges such as in the prototype would not be of major influence to the predictions.

An item of some interest is the reentrainment coefficients GAMA1 and GAMA2. Two runs D-FS-1 (GAMA1=0) and D-FS-2 (GAMA2=0.02) are made to investigate the effect of this coefficient. It is found that the rate of material accumulation on the surface is decreased for D-FS-2. At the same time, the values of x, z, σ_x^2, σ_z^2 at the surface and those very near the surface tend to be more nearly equal in D-FS-2. Both phenomena are expected physically.

In summary, the model predictions are all reasonable physically. When the coefficients are fully defined through experiments, both in the laboratory and the field, it is believed that the model will be a valuable tool in the assessment of the physical impact of barge discharge of solid wastes. Even in the present state, before the accurate determination of some of the coefficients, the model is believed capable of predicting the overall effects over the long run even though for each single discharge, the details may not be as accurately predicted.

It should be pointed out that in the graphs, wherever several different quantities are plotted versus the same independent variable, the scale of the ordinate for the various quantities are different. They are automatically set in such a way as to result in graphs which span a reasonable scale. For comparison purposes, attention is called to the headings where the maximum and minimum values of each plotted variable are noted. It should further be mentioned that the last point plotted corresponding to the largest value of the independent variable is a fictitious point used in setting the scale and should therefore be disregarded.

The coordinate system used for Barge Operation 1 is always an inertial system with the origin attached to the earth. For Barge Operations 2 and 3, the origin of the coordinate system is attached to the barge which is moving. However, after the time when the input to the long term diffusion model is completed, the motion of the coordinate system is arrested.

6.1 Interpretation of the Results of Computations from the Mathematical Model for Long Term Diffusion

The mathematical model developed for evaluating the long term diffusion phase of the phenomenon is based on the method of moments. Instead of obtaining the detailed concentration of the waste (both fluid and solid phases) in the environment, only their first few moments are obtained as functions of time and of the vertical coordinate. This greatly reduces the computational labor and yet retains the most significant aspects of the solution. The primary result of the calculations in each specific case consists, then, of $C_{ij}(y,t), (i,j = 0,1,2)$, the ijth moment of the concentration defined previously in Section 3.6.2. Their relations to the physically more meaningful quantities of centroid locations x_o, z_o, and variances σ_x^2, σ_z^2, σ_{xz} have also been discussed in Section 3.6.2. In the following, an interpretation will be given on the physical significance of each of the quantities.

a) C_{oo}

The quantity C_{oo} is simply the total amount of waste material at depth y and time t within a horizontal slab of unit thickness.

b) x_o, z_o

The quantities x_o, and z_o, are x and z coordinates of the centroid of the waste at depth y and time t.

c) σ_x^2, σ_z^2, σ_{xz}

These are the variances of the distribution at depth y and time t (see below for further discussion).

d) C_{max}

This is the peak concentration at depth y and time t based on the assumption that the distribution is Guassian.

All the above quantities are self-explanatory. Their physical significance are also clear. However, in the event $\sigma_{xz} \neq 0$, the relation between the variances σ_x^2, σ_z^2, σ_{xz} and the physical shape of the waste pool is somewhat obscure. An attempt will now be made to clarify this aspect.

A Guassian distributed waste pool with parameters

$$C_{oo},\ x_o,\ z_o,\ \sigma_x^2,\ \sigma_z,\ \sigma_{xz}$$

can be written

$$\frac{C_{oo}}{2\pi\sqrt{\sigma_x^2\sigma_z^2-\sigma_{xz}^2}}\ \exp\left\{\frac{-\sigma_x^2\sigma_z^2}{2(\sigma_x^2\sigma_z^2-\sigma_{xz}^2)}\left[\left(\frac{x-x_o}{\sigma_x}\right)^2+\left(\frac{z-z_o}{\sigma_z}\right)^2 - \frac{2\sigma_{xz}}{\sigma_x^2\sigma_z^2}\left(x-x_o\right)\left(z-z_o\right)\right]\right\}$$

By a rotation and a translation of the coordinates from x, z to x_1, z_1, it is possible to remove the terms containing x_o, z_o and xz in the exponent. The new axes x_1 z_1 are then the principal axes and the corresponding $\sigma_{x_1}^2$, $\sigma_{z_1}^2$, then correspond to the variances in the principal axes whose physical interpretation is more obvious. It can be demonstrated that the origin of the principal axes are at x_o, z_o with respect to the old axis and the clockwise angle θ which the old axes needs to be rotated is such that

$$\tan 2\theta = \frac{2\sigma_{xz}}{\sigma_x^2 - \sigma_z^2}$$

It can further be shown that the variances

$$\sigma_{x_1}^2, \sigma_{z_1}^2$$

in the principal axes are

$$\sigma_{x_1}^2 = \frac{\sigma_x^2 + \sigma_z^2}{2} + \sqrt{\frac{\left(\sigma_x^2 + \sigma_z^2\right)^2}{4} + \sigma_{xz}^2}$$

$$\sigma_{z_1}^2 = \frac{\sigma_x^2 + \sigma_z^2}{2} - \sqrt{\frac{\left(\sigma_x^2 - \sigma_z^2\right)^2}{4} + \sigma_{xz}^2}$$

from which it can be seen that

$$\sigma_{x_1}^2 \sigma_{z_1}^2 = \sigma_x^2 \sigma_z^2 - \sigma_{xz}^2$$

With the help of these equations, the physical interpretation of the variances can be readily made.

When solid waste such as dredge spoil is discharged into the ocean, an item of interest is the build up of the discharged material on the ocean floor. In the mathematical model developed in this investigation based on the method of moments, the following quantities are obtained as functions of time.

W	Total deposited solid
X	x-coordinate of centroid of deposited solid

Z	z-coordinate of centroid of deposited solid
σ_x^2	x-variance of deposited solid
σ_z^2	z-variance of deposited solid
σ_{xz}	covariance of deposited solid

The significance of the variances have already been discussed. Thus, a set of principal axes can be found and the variances in these axes obtained. In the present situation involving deposited solids, an additional item of interest is the maximum height h of the mound built up on the ocean floor. This can be shown to be

$$h = \frac{W}{2\pi\sqrt{\left(\sigma_x^2\sigma_z^2 - \sigma_{xz}^2\right)}(1-p)}$$

where p is the porosity in the deposited solids. In the above expression, a Guassian distribution is assumed. If the distribution were assumed to be more nearly uniform over the range

$$|x_1| < \alpha\sigma_{x_1}, \quad |z_1| < \alpha\sigma_{z_1},$$

where x_1 and z_1 are the centroidal principal axes, then

$$h \simeq \frac{W}{4\alpha^2\sqrt{\sigma_x^2\sigma_z^2 - \sigma_{xz}^2}\,(1-p)}$$

where α is a constant which may be taken to be, say, 2.

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APPENDIX A

COMPUTER PROGRAM

The computer program is described and listed in this appendix. It should be noted that the program listed was tested on a CDC 6600. Modifications may be necessary if it were to be adapted to other systems. It should further be cautioned that since the choice of such parameters as integration step size and grid points are built into the program, the efficiency of the processing is a function of the data for the particular case. Under certain circumstances, the program may not be able to choose a satisfactory step size to complete the calculations. The choices of step sizes are made assuming that

1) the waste load will descend into the ocean
2) the convective phase will terminate (either by reaching bottom or by reaching neutral buoyancy condition) in a reasonable amount of time.
3) the collapse phase can occur (either by reaching bottom or by being in a density gradient) and will terminate in a reasonable amount of time.

Several tries may be necessary in cases when the discharge and ambient conditions deviate from those envisioned in typical coastal waters. Section 3.7 should be consulted for more details.

READING SEQUENCE IN BARGE OPERATION 1

Symbol	Format	Subroutine
METHOD, IGCN, IGCL, IGLT, IPCN, IPCL, IPLT, NSCALE, NX, NY, IBUG	16I5	DISPSN
(TRIGER(I), I=1,4)	8F10.5	
N*	I10	AMBIENT
(Y(I), I=1, N)	8G10.4	
(ROA(I), I=1, N)	8G10.4	
YK1, YK2, YK3, YK4, AKY1,AKY2, AKY3	7G10.4	
YU, YW. YE, H, UA0, WA0	6G10.4	
TSTOP	G10.4	DUMP
ISIZE**, KEY1, KEY2, KEY3	4I10	
DINCR1, DINCR2+	2G10.4	
ALPHA0, BETA, CM, CD+	4G10.4	
GAMA, CDRAG, CFRIC, CD3, CD4, ALPHAC FRICTN, F1+	8G10.4	
ALFA1, ALFA2, GAMA1,GAMA2, ALAMDA+	5G10.4	
RB, ROO,U(1), V(1), W(1)	5G10.4	
K, L++	2I10	
(ROAS(I), I=1, K)	4G10.4	
((CS(I, J), J=1, L), I=1, K)	8G10.4	
((WS(I, J), J=1, L), I=1, K)	8G10.4	

* $N \leq 30$

** Option of 51, 101 or 151

+ Skip card if KEY 1 = 1

++ $K \leq 4$, $L \leq 2$

EXPLANATION OF THE INPUT SYMBOLS

In Program	In Text	Remarks
METHOD		Method of barge operation must be 1 for barge operation 1
IGCN	IGCN=0	No graph plotted for convective phase
	IGCN=1	One graph plotted for convective phase
	IGCN=2	Extra graphs of concentrations plotted for convective phase
IGCL	IGCL=0	No graph plotted for collapse phase
	IGCL=1	Graph plotted for collapse phase
IGLT	IGLT=0	No graph plotted for long term diffusion phase
	IGLT=1	Graphs of C_{00}, Size and settled solids characteristics plotted
	IGLT=2	Extra graphs of centroid locations plotted
	IGLT > 2	All graphs plotted for long term diffusion
IPCN	IPCN=0	No detailed printed output for convective phase
	IPCN=1	Detailed printed output included
IPCL	IPCL=0	No detailed printed output for collapse phase
	IPCL=1	Detailed printed output included
IPLT	IPLT=0	No detailed printed output for long term diffusion phase
	IPLT > 0	Approximate number of pages of detailed output desired before input to long term diffusion completed

In Program	In Text	Remarks
NSCALE		Scale for plotting
NX		Size of graph along independent variable
NY		Size of graph along dependent variable
IBUG		Number of integration steps between inputs to long term diffusion
TRIGER(I)		Triggers for graphing in long term diffusion (graphs are at times when the peak value of C_{00} in the y direction first falls below TRIGER(I) times the maximum of C_{00} ever achieved after input to long term diffusion completed).
N		Number of points where ambient density is specified
Y(I)	y	Vertical position from free surface where ambient density is specified (ft)
ROA(I)	ρ_a	Ambient density at Y(I), (gram/cc)
YK1, YK2, YK3, YK4	y_{k1}, y_{k2} y_{k3}, y_{k4}	Positions where the vertical diffusion coefficient changes (ft)
AKY1, AKY2, AKY3	k_{y1}, k_{y2} k_{y3}	Vertical diffusion coefficients: near to the free surface, at thermocline and below the thermocline (ft^2/sec)
YU, YW, YE	y_u, y_w, y_e	Vertical positions where ambient velocity is specified (ft)
H	H	Total depth (ft)

In Program	In Text	Remarks
UA0, WA0	u_a, w_a	Maximum horizontal velocities in x and z directions (ft/sec)
TSTOP		Physical time limit in second in the long term diffusion computation. Time started from the commencement of dumping.
ISIZE		Vertical grid point size in the long term diffusion computation, 3 options: 51, 101, and 151
KEY1		KEY1=1 Use Tetra Tech suggested coefficients KEY1=2 Use read in coefficients
KEY2		KEY2=1 The computation stops at the end of convective descent phase KEY2=2 The computation stops at the end of dynamic collapse KEY2=3 The computation stops at the end of long term diffusion
KEY3		KEY3=0 Long term diffusion computation also performed for the fluid part KEY3=1 No long term diffusion performed for the fluid part
DINCR1		Factor in obtaining suitable trial time step in the convective descent phase
DINCR2		Factor in obtaining suitable trial time step in the dynamic collapse phase

In Program	In Text	Remarks
ALPHAC	α_c	Entrainment coefficient for collapsing
ALPHA0	α_o	Entrainment coefficient for a thermal
BETA	β	Settling coefficient
CM	C_m	Added mass coefficient
CD	C_D	Drag coefficient
GAMA	γ	Gradient factor in the cloud
CDRAG	C_{drag}	Form drag coefficient for the quadrant of a collapsing ellipsoid
CFRIC	C_{fric}	Skin friction coefficient for the quadrant of a collapsing ellipsoid
CD3	C_{D3}	Drag coefficient for an ellipsoidal wedge
CD4	C_{D4}	Drag coefficient for a plate
FRICTN	F_{rictn}	Friction coefficient between the cloud and ocean bottom
F1	F_1	Modification factor used in computing the resistance of the friction force to the collpse of a quadrant of an ellipsoid
ALFA1	α_1	Absorbency coefficient of the bed to the solid particles
ALFA2	α_2	Absorbency coefficient of the free surface to the solid particles

In Program	In Text	Remarks
GAMA1	γ_1	Entrainment coefficient (for resuspension) at the bed
GAMA2	γ_2	Entrainment coefficient (for resuspension) at the free surface
ALAMDA	λ	Dissipation factor used in computing the horizontal diffusion coefficient
RB	b	Initial radius of the waste material (ft)
ROO	ρ	Density of the waste material (gram/cc)
U(1)	u	Initial velocity in x direction (ft/sec)
V(1)	v	Initial velocity in y direction (ft/sec)
W(1)	w	Initial velocity in z direction (ft/sec)
K	K	Number of different solid density
L	L	Number of different solid fall velocities for each solid density
ROAS(I)	ρ_s	Solid density (gm/cc)
CS(I, J)	C_s	Concentration of solid particles with a specific density ROAS(I) and fall velocity WS(I, J), (ft^3/ft^3)
WS(I, J)	W_s	Fall velocity of the solid particles with density ROAS(I) (ft/sec)

EXPLANATION OF OUTPUT SYMBOLS

In Convective Descent and Dynamic Collapse Phase

In Program	In Text	Remarks
TIME		Physical time from conmencement of dumping (sec)
X, Y, Z	x, y, z	Position of the centroid of the cloud in x, y, and z direction respectively (ft)
U, V, W	u, v, w	Velocity of the cloud in x, y, and z direction respectively (ft/sec)
DEN-DIF	$\rho - \rho_a$	Density difference between that of the cloud and the ambient (gram/cc)
RADIUS	b	Radius of the hemispherical cloud (ft)
VORT.	K	Vorticity of the cloud (sec^{-1})
ALPHA	α	Entrainment coefficient
FLUID CONC.	$1-\sum_{i=1}^{K}\sum_{j=1}^{L} C_{sij}$	Concentration of the fluid part of waste material (ft^3/ft^3)
SOLID VOL.		Solid volume of waste material with a specific fall velocity (ft^3)
CONCENTRATION	C_{sij}	Concentration of the solid particle with a specific fall velocity
A	a	Minor axis of the waste material in dynamic collapse phase
B	b	Major axis of the waste material in dynamic collapse phase

In Long Term Diffusion

In Program	In Text	
TIME		Physical time from the commencement of barge operation
MEAN Y		The centroid of waste material in y direction
FALL VEL.	w_{sij}	Fall velocity of the solid particles
TSS		Total suspended solid
T		Total boundary material
Y		Position of grid point
X, Z		Centroid of waste material on a horizontal plane at Y
SIGMAX,	σ_x^2,	Variances of the waste material on a horizontal plane at Y
SIGMAZ,	σ_z^2,	
SIGMXZ	σ_{xz}	
CONC.		Concentration assuming the waste material is normally distributed
COO	C_{oo}	$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} C \, dxdz$ at Y

For Solid on the Bed or Free Surface

X, Z	Centroid of deposited waste material
SIGMAX, SIGMAZ, SIGMXZ	Variances of the deposited waste material
SIZE	Geometric mean of σ_x and σ_z along principle axes
DEPOSITED SOLID	Solid deposited either on bed or free surface

READING SEQUENCE IN BARGE OPERATION 2

Symbol	Format	Subroutine
METHOD, IGCN, IGCL, IGLT, IPCN, IPCL, IPLT, NSCALE, NX, NY, IBUG	16I5	DISPSN
(TRIGER(I), I=1, 4)	8F10.5	
N*	I10	AMBIENT
(Y(I), I=1, N)	8G10.4	
(ROA(I), I=1, N)	8G10.4	
YK1, YK2, YK3, YK4, AKY2, AKY3	7G10.4	
YU, YW, YE, H, UA0, WA0	6G10.4	
TSTOP	G10.4	JET
ISIZE**, KEY1, KEY2, KEY3	4I10	
DINCR1, DINCR2+	2G10.4	
ALPHA1, ALPHA2, BETA, CD+	4G10.4	
GAMA, CDRAG, CFRIC, CD3, CD4, ALPHA3, ALPHA4, FRICTN, F1, CM+	8G10.4	
ALFA1, ALFA2, GAMA1, GAMA2, ALAMDA+	5G10.4	
BC(1), ROO, THETA2(1), U(1), CY(1)	5G10.4	
K, L++	2I10	
(ROAS(I), I=1, K)	4G10.4	
((CS(I, J), J=1, L), I=1, K)	8G10.4	
((WS(I, J), J=1, L), I=1, K)	8G10.4	
UB, SAI, TIME	3G10.4	

* N ≤ 30

** Option of 51, 101, or 151

+ Skip card if KEY 1 = 1

++ K ≤ 4, L ≤ 2

EXPLANATION OF THE INPUT SYMBOLS

In Program	In Text	Remarks
METHOD		Method of barge operation must be 2 for barge operation 2
IGCN	IGCN=0	No graph plotted for convective phase
	IGCN=1	One graph plotted for convective phase
	IGCN=2	Extra graphs of concentrations plotted for convective phase
IGCL	IGCL=0	No graph plotted for collapse phase
	IGCL=1	Graph plotted for collapse phase
IGLT	IGLT=0	No graph plotted for long term diffusion phase
	IGLT=1	Graphs of C_{00}, Size and settled solids characteristics plotted
	IGLT=2	Extra graphs of centroid locations plotted
	IGLT >2	All graphs plotted for long term diffusion
IPCN	IPCN=0	No detailed printed output for convective phase
	IPCN=1	Detailed printed output included
IPCL	IPCL=0	No detailed printed output for collapse phase
	IPCL=1	Detailed printed output included
IPLT	IPLT=0	No detailed printed output for long term diffusion phase
	IPLT >0	Approximate number of pages of detailed output desired before input to long term diffusion completed

In Program	In Text	Remarks
NSCALE		Scale for plotting
NX		Size of graph along independent variable
NY		Size of graph along dependent variable
IBUG		Number of integration steps between inputs to long term diffusion
TRIGER(I)		Triggers for graphing in long term diffusion (graphs are at times when the peak value of C_{00} in the y direction first falls below TRIGER(I) times the maximum of C_{00} ever achieved after input to long term diffusion completed).
N		Number of points where ambient density is specified
Y(I)	y	Vertical position from free surface where ambient density is specified (ft)
ROA(I)	ρ_a	Ambient density at Y(I), (gram/cc)
YK1, YK2, YK3, YK4	y_{k1}, y_{k2} y_{k3}, y_{k4}	Positions where the vertical diffusion coefficient changes (ft)
AKY1, AKY2, AKY3	k_{y1}, k_{y2} k_{y3}	Vertical diffusion coefficients: near to the free surface, at thermocline and below the thermocline (ft^2/sec)
YU, YW, YE	y_u, y_w, y_e	Vertical positions where ambient velocity is specified (ft)
H	H	Total depth (ft)

In Program	In Text	Remarks
UA0, WA0	u_a, w_a	Maximum horizontal velocities in x and z directions (ft/sec)
TSTOP		Physical time limit in second in the long term diffusion computation. Time started from the commencement of discharging through the jet.
ISIZE		Vertical grid point size in the long term diffusion computation, 3 options: 51, 101, and 151
KEY1		KEY1=1 Use Tetra Tech suggested coefficients KEY1=2 Use read in coefficients
KEY2		KEY2=1 The computation stops at the end of jet convection KEY2=2 The computation stops at the end of dynamic collapse KEY2=3 The computation stops at the end of long term diffusion
KEY3		KEY3=0 Long term diffusion computation also performed for the fluid part KEY3=1 No long term diffusion performed for the fluid part
DINCR1		Trial value in obtaining distance step DS= DINCR1 x BC(1) in the jet convection phase where BC = jet size
DINCR2		Trial value in obtaining distance step DS = DINCR2 x BC(INDEX) in the dynamic collapse phase, where INDEX is the step at the end of jet convection

In Program	In Text	Remarks
ALPHA1	α_1	Entrainment coefficient for a momentum jet
ALPHA2	α_2	Entrainment coefficient for 2-D thermal
BETA		Settling coefficient
CD		Drag coefficient for a cylinder
GAMA		Gradient factor in the cloud
CDRAG		Form drag coefficient for the quadrant of a collapsing elliptical cylinder
CFRIC		Skin drag coefficient for the quadrant of a collapsing elliptical cylinder
CD3		Drag coefficient for an elliptical wedge
CD4		Drag coefficient for a two-dimensional plate
FRICTN		Friction coefficient between the cloud and ocean bottom
F1		Modification factor used in computing the the resistance of the friction force to the quadrant of an elliptical cylinder
CM		Added mass coefficient
ALFA1		Absorbency coefficient of the bed to the solid particles
ALFA2		Absorbency coefficient of the free surface to the solid particles
GAMA1		Entrainment coefficient (for resuspension) at the bed

GAMA2		Entrainment coefficient (for resuspension) at the surface
ALAMDA		Dissipation factor used in computing the horizontal diffusion coefficient
BC(1)	b	Radius of nozzle (ft)
ROO	ρ	Density of the waste material (gram/cc)
THETA2(1)	θ_2	Angle of the nozzle (degree)
U(1)	u	Velocity of the waste material at the nozzle (ft/sec)
CY(1)	y	Vertical position of the nozzle (ft)
K		Number of different solid density
L		Number of different solid fall velocities for each solid density
ROAS(I)		Solid density (gm/cc)
CS(I, J)		Solid concentration of the solid particles with density ROAS(I) and fall velocity WS(I, J) (ft^3/ft^3)
WS(I, J)		Fall velocity of the solid particles (ft/sec)
UB		Barge velocity (ft/sec)
SAI		Barge moving direction (limited to 180° - 270°)
TIME		Time of continuous discharge (sec)

EXPLANATION OF OUTPUT SYMBOLS

In Jet Convection And Dynamic Collapse Phase

In Program	In Text	Remarks
TIME		Physical time taken for the front of jet to move from the nozzle to position S (sec)
S	s	Distance along the axis of the jet (ft)
X, Y, Z	x, y, z	Position of the center of the jet at position S (ft)
U	u	Velocity of the jet at S (ft/sec)
RADIUS	b	Radius of the jet (ft)
DEN-DIF	$\rho - \rho_a$	Density difference between that of the jet and the ambient (gram/cc)
FLUID CONC.		Concentration of the fluid part waste material
FLUX OF SOLID	$u \pi b^2 C_{sij}$	Flux of solid particles through a cross section at S (ft^3/ft^3)
CONCENTRATION	C_{sij}	Concentration of solid particles with a specific fall velocity (ft^3/ft^3)
A	a	The minor axis of the two dimensional thermal in the dynamic collapse phase (ft)
B	b	The major axis of the two dimensional thermal with length DS (ft)

In Program	In Text	Remarks
SOLID VOL.		Solid volume in the two-dimensional thermal with length DS (ft^3)

In Long Term Diffusion

See Explanation of Output Symbols In Barge Operation 1

READING SEQUENCE IN BARGE OPERATION 3

Symbol	Format	Subroutine
METHOD, IGCN, IGCL, IGLT, IPCN, IPCL, IPLT, NSCALE, NX, NY, IBUG	16I5	DISPSN
(TRIGER(I), I=1,4)	8F10.5	
N*	I10	AMBIENT
(Y(I), I=1, N)	8G10.4	
(ROA(I), I=1, N)	8G10.4	
YK1, YK2, YK3, YK4, AKY1, AKY2, AKY3	7G10.4	
YU, YW, YE, H, UA0, WA0	6G10.4	
TSTOP	G10.4	WAKE
ISIZE**, KEY1, KEY2, KEY3	4I10	
C1, C2+	2G10.4	
DINCR1, DINCR2+	2G10.4	
ALPHA, BETA, CD1, CD2, CM , ALPHA1+	8G10.4	
GAMA, CDRAG, CFRIC, CD3, CD4, ALPHA3, ALPHA4, FRICTN, F1+	8G10.4	
ALFA1, ALFA2, GAMA1, GAMA2, ALAMDA+	5G10.4	
ROO, QD, BB, DD	4G10.4	
K, L++	2I10	
(ROAS(I), I=1, K)	4G10.4	
((CS(I, J), J=1, L), I=1, K)	8G10.4	
((WS(I, J), J=1, L), I=1, K)	8G10.4	
UB, SAI, TIME	3G10.4	

* N ≤ 30

** Option of 51, 101, 151

+ Skip card if KEY 1 = 1

++ K ≤ 4, L ≤ 2

EXPLANATION OF THE INPUT SYMBOLS

In Program	In Text	Remarks
METHOD		Method of barge operation must be 3 for barge operation 3
IGCN	IGCN=0	No graph plotted for convective phase
	IGCN=1	One graph plotted for convective phase
	IGCN=2	Extra graphs of concentrations plotted for convective phase
IGCL	IGCL=0	No graph plotted for collapse phase
	IGCL=1	Graph plotted for collapse phase
IGLT	IGLT=0	No graph plotted for long term diffusion phase
	IGLT=1	Graphs of C_{00}, Size and settled solids characteristics plotted
	IGLT=2	Extra graphs of centroid locations plotted
	IGLT >2	All graphs plotted for long term diffusion
IPCN	IPCN=0	No detailed printed output for convective phase
	IPCN=1	Detailed printed output included
IPCL	IPCL=0	No detailed printed output for collapse phase
	IPCL=1	Detailed printed output included
IPLT	IPLT=0	No detailed printed output for long term diffusion phase
	IPLT >0	Approximation number of pages of detailed output desired before input to long term diffusion completed

In Program	In Text	Remarks
NSCALE		Scale for plotting
NX		Size of graph along independent variable
NY		Size of graph along dependent variable
IBUG		Number of integration steps between inputs to long term diffusion
TRIGER(I)		Triggers for graphing in long term diffusion (graphs are at times when the peak value of C_{00} in the y direction first falls below TRIGER(I) times the maximum of C_{00} ever achieved after input to long term diffusion completed).
N		Number of points where ambient density is specified
Y(I)	y	Vertical position from free surface where ambient density is specified (ft)
ROA(I)	ρ_a	Ambient density at Y(I), (gram/cc)
YK1, YK2, YK3, YK4	y_{k1}, y_{k2} y_{k3}, y_{k4}	Positions where the vertical diffusion coefficient changes (ft)
AKY1, AKY2, AKY3	k_{y1}, k_{y2} k_{y3}	Vertical diffusion coefficients: near to the free surface, at thermocline and below the thermocline (ft^2/sec)
YU, YW, YE,	y_u, y_w, y_e	Vertical positions where ambient velocity is specified (ft)
H	H	Total depth (ft)

In Program	In Test	Remarks
UA0, WA0	u_a, w_a	Maximum horizontal velocities in x and z directions (ft/sec)
TSTOP		Physical time limit in second in the long term diffusion computation. Time started from the commencement of discharging into the wake
ISIZE		Vertical grid point size in the long term diffusion computation, 3 options: 51, 101, and 151
KEY1		KEY1=1 Use Tetra Tech suggested coefficients KEY1=2 Use read in coefficients
KEY2		KEY2=1 The computation stops at the end of convective decend KEY2=2 The computation stops at the end of dynamic collapse KEY2=3 The computation stops at the end of long term diffusion
KEY3		KEY3=0 Long term diffusion computation also performed for the fluid part KEY3=1 No long term diffusion performed for the fluid part
C1, C2	c_1, c_2	Barge shape factors, used in computing plume size $BC(1) = 2\ (C_1 \times C_2^{1/3}) \times (BB \times DD)^{1/2}$ where BC = plume size, BB = barge width, DD = barge draft
DINCR1		Trial value in obtaining distance step DS = DINCR1 x BC (1) in the convective decend phase

In Program	In Text	Remarks
DINCR2		Trial value in obtaining distance step DS = DINCR2 x BC (INDEX) in the dynamic collapse phase, where INDEX is the step at the end of convective decend
ALPHA	α	Entrainment coefficient for 2 - D thermal
BETA	β	Settling coefficient
CD1	C_{D1}	Drag coefficient for a half cylinder wedge
CD2	C_{D2}	Drag coefficient for a cylinder
CM	C_m	Added mass coefficient
ALPHA1	α_1	Entrainment coefficient for a jet
GAMA	γ	Gradient factor in the cloud
CDRAG	C_{drag}	Form drag coefficient for the quadrant of a collapsing elliptical cylinder
CFRIC	C_{fric}	Skin drag coefficient for the quadrant of a collapsing elliptical cylinder
CD3	C_{D3}	Drag coefficient for an elliptical wedge
CD4	C_{D4}	Drag coefficient for a two-dimensional plate
FRICTN	F_{rictn}	Friction coefficient between the cloud and ocean bottom
F1	F_1	Modification factor used in computing the the resistance of the friction force to quadrant of an elliptical cylinder
CM	C_m	Added mass coefficient

In Program	In Text	Remarks
ALFA1	α_1	Absorbency coefficient of the bed to the solid particles
ALFA2	α_2	Absorbency coefficient of the free surface to the solid particles
GAMA1	γ_1	Entrainment coefficient at the bed
GAMA2	γ_2	Entrainment coefficient at the bed
ALAMDA	λ	Dissipation factor used in computing the horizontal diffusion coefficient
ROO	ρ	Density of the waste material (gram/cc)
QD	q_d	Discharge rate of the waste material (ft^3/sec)
BB	B	Barge width (ft)
DD	D	Barge depth (ft)
K	K	Number of different solid density
L	L	Number of different solid fall velocities for each solid density
ROAS(I)	ρ_s	Solid density
CS(I, J)	C_s	Solid concentration of the solid particles with density ROAS(I) and fall velocity WS(I, J) (ft^3/ft^3)
WS(I, J)	W_s	Fall velocity of the solid particles
UB		Barge velocity (ft/sec)

In Program	In Text	Remarks
SAI		Barge moving direction (limited to $180^\circ \sim 270^\circ$)
TIME		Time of continuous discharge (sec)

EXPLANATION OF OUTPUT SYMBOLS

In Convective Descent And Dynamic Collapse

In Program	In Text	Remarks
TIME		Physical time taken for a two-dimensional thermal to move to position S (sec)
S	s	Distance along the path of a two-dimensional thermal (ft)
X, Y, Z	x, y, z	Position of the two-dimensional thermal at S (ft)
U		Velocity of the two-dimensional thermal at S (ft/sec)
RADIUS	b	Radius of a half cylinder thermal (ft)
DEN-DIF	$\rho-\rho_a$	Density difference between that of the two-dimensional thermal and the ambient (gram/cc)
FLUID CONC.		Concentration of the fluid part waste material
SOLID VOL.		Solid volume in the two-dimensional thermal with length DS (ft)
CONCENTRATION	C_{sij}	Concentration of solid particles with a specific fall velocity (ft^3/ft^3)
A	a	The minor axis of the two-dimensional thermal in the in the dynamic collapse phase (ft)

Program	In Text	Remarks
	b	The major axis of the two-dimensional thermal in the dynamic collapse phase (ft)

In the Long Term Diffusion Phase

See Explanation of Output Symbols in Barge Operation 1

```
      PROGRAM DISPSN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C     PROGRAM FOR PREDICTING THE FATE OF WASTE MATERIAL DISCHARGED
C     FROM A BARGE INTO THE OCEAN   ENVIRONMENT
C
C
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /A/ EP(20)
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /C/X0,Z0
      COMMON /MATRIX/ A(151),B(151),C(151),CP(151)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YF,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON        CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),FLUX(600),DENDIF(600),DUMY1(600),
     ,CZ(600),SS(8,600),DAMY2(6,600),USEJET(600),USEDMP(600),BC(600),
     ,WS(4,2) ,
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /COMPUT/EE(7,151),E(20),BLANK(123),CS(4,2),
     ,    D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/SIZE/NX,NY
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON/KOH1/ INDE ,TRIGER(4),CMAXMAX,TOTMAX,KKK
      COMMON/KOH2/ IFINISH
      COMMON/GRAPH/TIM(4)
      COMMON/DEBUG/IBUG
C
      DATA G,PAI/32.2,3.14159/
C
    4 CONTINUE
      UBX=0.
      WBZ=0.
      READ(5,10) METHOD,IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE,NX,NY,IBUG
      IF(METHOD.LT.1) CALL EXIT
      READ(5,20) ( TRIGER(I),I=1,4)
   20 FORMAT(8F10.5)
      TIM(4)=0.
      CMAXMAX=0.
      TOTMAX=0.
      IFINISH=0
      KKK=0
      INDE =1
      ISUM=IGCN+IGCL+IGLT+IPCN+IPCL+IPLT
      IF(ISUM.EQ.0) CALL EXIT
      CALL AMBIENT
   10 FORMAT(16I5)
C     NO. OF BARGE OPERATION
C     1   3 DIMENSIONAL AXI -SYMMETRIC   INSTANTANEOUS RELEASE OF
C         THE WASTE LOAD FROM A BARGE
C     2   TIME LIMITED CONTINUOUS DISCHARGE OF THE WASTE MATERIAL THROUGH
C         A NOZZLE UNDER THE BOTTOM OF A MOVING BARGE
C     3   TIME LIMITED CONTINUOUS DISCHARGE OF THE WASTE MATERIAL INTO
C         THE WAKE OF A MOVING BARGE
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```
      GO TO (1,2,3) METHOD
    1 CALL DUMP
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 1) GO TO 100
      IF(IPLUNG.EQ.1) GO TO 800
      NNN=N-1
      DO 888 III=1,NNN
      IF(CY(ISTEP).GE.Y(III).AND.CY(ISTEP).LE.Y(III+1)) DENGRA=
     * ROA(III+1)-ROA(III)
  888 CONTINUE
      IF(DENGRA.GT.1.E-10) GO TO 800
      WRITE(6,666)
      IF(KEY2.EQ.2) GO TO 100
      NNCC=K*L
      DO 2001 IAM=1,NNCC
 2001 CMAX(IAM)=SS(IAM,ISTEP)
      CMAX(NNCC+1)=USEDMP(ISTEP)
      IF(WS(1,1).EQ.0.) CMAX(1)=CMAX(2)
      YY=CY(ISTEP)
      A0=0.5*BC(ISTEP)
      IF(YY-A0.LT.0.) YY=A0
  666 FORMAT(1H1,10X,  38HGRADIENT=0 GO DIRECTLY TO LT DIFFUSION)
      CALL DIFUSN1
      GO TO 100
  800 CONTINUE
      CALL COLAPS1
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 2) GO TO 100
   11 CALL DIFUSN1
      GO TO 100
    2 CALL JET
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 1) GO TO 100
      IF(NOTE  .EQ.1) GO TO 700
      NNN=N-1
      DO 777 III=1,NNN
      IF(CY(ISTEP).GE.Y(III).AND.CY(ISTEP).LE.Y(III+1)) DENGRA=
     * ROA(III+1)-ROA(III)
  777 CONTINUE
      IF(DENGRA.GT.1.E-10) GO TO 700
      WRITE(6,666)
      IF(KEY2.EQ.2) GO TO 100
      NNCC=K*L
      DO 2002 IAM=1,NNCC
 2002 CMAX(IAM)=SS(IAM,ISTEP)
      CMAX(NNCC+1)=USEJET(ISTEP)
      IF(WS(1,1).EQ.0.) CMAX(1)=CMAX(2)
      YY=CY(ISTEP)
      A0=    BC(ISTEP)
      IF(YY-A0.LT.0.) YY=A0
      DT2=DT/U(ISTEP)
      INDEX=ISTEP
      CALL DIFUSN2
      GO TO 100
  700 CONTINUE
      CALL COLAPS2
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 2) GO TO 100
      CALL DIFUSN2
      GO TO 100
    3 CALL WAKE
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 1) GO TO 100
      IF(NOTE  .EQ.1) GO TO 900
      NNN=N-1
      DO 999 III=1,NNN
      IF(CY(ISTEP).GE.Y(III).AND.CY(ISTEP).LE.Y(III+1)) DENGRA=
     * ROA(III+1)-ROA(III)
  999 CONTINUE
      IF(DENGRA.GT.1.E-10) GO TO 900
      WRITE(6,666)
      IF(KEY2.EQ.2) GO TO 100
      NNCC=K*L
      DO 2003 IAM=1,NNCC
 2003 CMAX(IAM)=SS(IAM,ISTEP)
      CMAX(NNCC+1)=USEJET(ISTEP)
      IF(WS(1,1).EQ.0.) CMAX(1)=CMAX(2)
      DT2=DT/U(ISTEP)
      INDEX=ISTEP
      YY=CY(ISTEP)
      A0=0.5*BC(ISTEP)
      IF(YY-A0.LT.0.) YY=A0
      CALL DIFUSN2
      GO TO 100
  900 CONTINUE
      CALL COLAPS2
      IF(IJK .GE. 5) GO TO 40
      IF(KEY2 .EQ. 2) GO TO 100
      CALL DIFUSN2
      GO TO 100
   40 WRITE(6,10001)DT
10001 FORMAT(1X,28H***THE STEP INCREMENT BEFORE,
     ,    34H LONG TERM DIFFUSION IN TROUBLE***, 3H $$,F12.4)
  100 CONTINUE
      GO TO 4
      END
VV
```

```
      SUBROUTINE AMBIENT
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTF,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
C
C
      READ(5,1)N
    1 FORMAT(I10)
C     N=NO. OF DATA PTS. ON DENSITY
      READ(5,2)(Y(I),I=1,N)
      READ(5,2)(ROA(I),I=1,N)
    2 FORMAT(8G10.4)
C     Y(N) MUST BE EQUAL TO THE TOTAL DEPTH
C     Y=DEPTH
C     ROA=AMBIENT DENSITY
      WRITE(6,3)
    3 FORMAT(1H1,10X,18HAMBIENT CONDITIONS/10X,14HDEPTH IN FT.
     ,   25HDENSITY IN GRAM PER CC.  ,21HKY IN SQFT PER SEC.
     ,    14HVEL. IN FPS.  )
      DO 10 J=1,N,8
      JJ=J+7
      IF(JJ .GE. N)JJ=N
      WRITE(6,4)(Y(I),I=J,JJ)
    4 FORMAT(10X,5HDEPTH,9X,8E12.4)
      WRITE(6,5)(ROA(I),I=J,JJ)
    5 FORMAT(10X,11HAMB-DENSITY, 3X,8E12.4)
   10 WRITE(6,6)
    6 FORMAT(/)
      DO 20 I=1,N
   20 ROA(I)=ROA(I)*1.94
      READ(5,2)YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3
C     YK=THE VERTICAL POSITIONS WHERE KY CHANGES VALUES
C     AKY=KY VALUE
      WRITE(6,7)YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3
    7 FORMAT(10X,2HYK,13X,4E12.4/10X,2HKY,13X,3E12.4/)
      READ(5,2)YU,YW,YE,H,UA0,WA0
C    YU=THE POSITION UA STARTS TO DECREASE
C    YW=THE POSITION WA HAS ITS MAX.VALUE
C    YE=THE POSITION AMB-VEL. GO TO ZERO
C    H=TOTAL DEPTH
C    UA0 WA0= AMB-VEL.
      WRITE(6,8)YU,YW,YE,H,UA0,WA0
    8 FORMAT(10X,3HYU ,E10.4,3HYW ,E10.4,3HYE ,E10.4,2HH ,E10.4/10X,
     ,3HUA ,E10.4,3HWA ,E10.4/)
      IY=N
      RETURN
      END
VV
```

```
      SUBROUTINE DUMP
C     3-DIMENSIONAL AXI -SYMMETRIC   INSTANTANEOUS RELEASE OF THE WHOLE
C     LOAD FROM BARGE
C
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON         CX(600),CY(600),AA     (600),U(600),
     ,    V(600),    W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,CZ(600),SS(8,600),SAVE(600),DUMY2(6,600),FC(600),HC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UH,SAI,TIME,ISTEP,  VF,
     ,               UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /COMPUT/EE(7,151),E(20),ACONC(123),CS(4,2),
     ,   O(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,               CCMAX(151),VAR(151)
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     , ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     , ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON/AUXX/AUX(600,8)
C
C
      IJK=0
      KV=1
C     KV CONST ABOUT VORTICITY GENERATION
      IBED=0
      ILEAVE=0
      NGRID=2
      WRITE(6,2)
    2 FORMAT(    //10X,17HBARGE OPERATION 1,
     ,              //10X,37HWASTE MATERIAL DUMPED INSTANTANEOUSLY,
     ,  15H INTO THE OCEAN,
     ,   //10X,50HTHE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE)
      READ(5,    1)TSTOP
      WRITE(6,90069)TSTOP
90069 FORMAT(/10X,5HTSTOP,F12.4,4HSEC./)
C     TIME LIMIT IN THE COMPUTATION
      READ(5,    6)ISIZE,KEY1,KEY2,KEY3
C     KEY1=1  USE TETRA TECH SUGGESTED COEFFICIENTS
C     KEY1=2  USE READ IN COEFFICIENTS
C     KEY2=1 COMPUTATION STOPS AT THE END OF CONVECTIVE DESCENT
C     KEY2=2 COMPUTATION STOPS AT THE END OF DYNAMIC COLLAPSE
C     KEY2=3 COMPUTATION STOPS AT THE END OF LONG TERM DIFFUSION
C     KEY3=0 LONG TERM DIFFUSION FOR FLUID PART ALSO
C     KEY3=1 NO LONG TERM DIFFUSION FOR FLUID PART
      WRITE(6,90074)ISIZE,KEY1,KEY2,KEY3
90074 FORMAT(10X,15HGRID POINT SIZE,I5,5H KEY1,I5,5H KEY2,I5,5H KEY3,I5)
      IF (KEY1 .EQ. 2) GO TO 500
      WRITE(6,90070)
90070 FORMAT(/10X,37HUSE TETRA TECH SUGGESTED COEFFICIENTS/)
      DINCR1=1.
      DINCR2=1.
      ALPHA0=.235
      BETA=0.
      CM=1.
      CD=.5
      CDRAG=1.
      GAMA=.25
      CFRIC=.01
      CD3=.1
      CD4=1.
      ALPHAC=.001
      FRICTN=.01
      F1=.1
      ALFA1=1.
      ALFA2=1.
      GAMA1=0.
      GAMA2=0.
      ALAMDA=0.001
      GO TO 501
  500 WRITE(6,90071)
90071 FORMAT(/10X,24HUSE READ IN COEFFICIENTS/)
      READ(5,1)DINCR1,DINCR2
      READ(5,1)ALPHAO,BETA,CM,CD
    1 FORMAT(8G10.4)
C     ALPHAO-ENTRAINMENT COEF.
C     BETA-SETTLING COEF.
C     CM-ADDED MASS COEF.
C     CD-DRAG COEF.
      READ(5,    1)GAMA,CDRAG,CFRIC,CD3,CD4,ALPHAC        ,FRICTN,F1
      READ(5,    1)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
  501 CONTINUE
      WRITE(6,90073)DINCR1,DINCR2
90073 FORMAT(10X,6HDINCR1,F10.4,7H DINCR2,F10.4)
      WRITE(6,4)ALPHAO,BETA,CM,CD
    4 FORMAT(10X,6HALPHAO,F10.4,5H BETA,F10.4,3H CM,F10.4,3H CD,F10.4)
      WRITE(6,90072)GAMA,CDRAG,CFRIC,CD3,CD4,ALPHAC        ,FRICTN,F1
90072 FORMAT(10X, 4HGAMA,F5.2,6H CDRAG,F5.2,6H CFRIC, F5.3,4H CD3,F5.2,
     ,   4H CD4,F5.2,7H ALPHAC,F10.4  ,/9X,          ,7H FRICTN,F10.4,
     ,      3H F1,F10.4)
      WRITE(6,90068)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
90068 FORMAT(10X,5HALFA1,F10.4,6H ALFA2,F10.4,6H GAMA1,F10.4,
     ,     6H GAMA2,F10.4,/9X,7H ALAMDA,F10.4/)
      READ(5,1)RB,ROO,U(1),V(1),W(1)
C     INITIAL CONDITIONS
C     RB-RADIUS
C     ROO -DENSITY OF WASTE MATERIAL
C     U,V,W,-INITIAL VEL.
      WRITE(6,5)RB,ROO,U(1),V(1),W(1)
    5 FORMAT(10X,2HRB,E12.4,4H ROO,E12.4,2H U,E12.4,2H V,E12.4,2H W,
     ,    F12.4)
      ROO=ROO*1.94
      READ(5,6)K,L
    6 FORMAT(8I10)
C     K-NO. OF DIFFERENT SOLID DENSITIES
C     L-NO. OF DIFFERENT FALL VEL.FOR A SPECIFIC DENSITY
      WRITE(6,7)K,L
    7 FORMAT(15X,3H  K,I5,3H  L,I5)
      READ(5,1)(ROAS(I),I=1,K)
      READ(5,1)((CS(I,J),J=1,L),I=1,K)
      READ(5,1)((WS(I,J),J=1,L),I=1,K)
      WRITE(6,10)(ROAS(I),I=1,K)
   10 FORMAT(10X,16HDENSITY OF SOLID, 8X,4E12.4)
      WRITE(6,11)
   11 FORMAT(10X,13HCONCENTRATION)
      DO 101 J=1,L
  101 WRITE(6,16)(CS(I,J),I=1,K)
   16 FORMAT(34X,4E12.4)
      WRITE(6,12)
   12 FORMAT(10X,22HFALL VELOCITY OF SOLID)
      DO 102 J=1,L
  102 WRITE(6,16)(WS(I,J),I=1,K)
      DO 200 I=1,K
  200 ROAS(I)=ROAS(I)*1.94
      ROAA=ROA(1)
      C1=(ROO-ROA(1))/ROA(1)
      E1=(ROA(IY)-ROA(1))/(H*ROA(1))
      F =V(1)/SQRT(G*C1*RB)
      EE1=E1*RB/C1
      IF(ROA(IY) .EQ. ROA(1))34,35
   34 IF(V(1) .EQ. 0.)36,37
   36 DT=5.
      GO TO 38
   37 DT =.01*RB*F *(1.+ALPHA0*H/RB)**2/(V(1)*2.)
      GO TO 38
   35 IF(V(1) .EQ. 0.)36,39
   39 DT=.01*PAI*F /SQRT(EE1)
C     CRITERION FROM CONDITION OF STRATIFICATION
      DT1=.01*RB*F *(1.+ALPHA0*H/RB)**2/(V(1)*2.)
C     CRITERION FROM UNIFORM AMBIENT
      IF(DT-DT1) 31,32,32
   31 CONTINUE
      GO TO 38
   32 DT =DT1
   38 CONTINUE
      ROU=ROO
C     SAVE ROO IN CASE RECOMPUTATION IS NEEDED
      ALPHA=ALPHA0
      DINCR=DINCR1
      WRITE(6,1973)
 1973 FORMAT(1H1,10X,18HCONVECTIVE DESCENT,/)
   25 ROO=ROU
      IJK=IJK+1
      E(1)=0.
      E(2)=0.
      E(3)=0.
C     POSITION
      VOLUME=2.*PAI*RB**3/3.
      E(4)=ROO*VOLUME
C     MASS
      CMMASS=CM*E(4)
      E(5)=CMMASS*U(1)
      E(6)=CMMASS*V(1)
      E(7)=CMMASS*W(1)
C     MOMENTUM
      E(8)=(ROA(1)-ROO)*VOLUME
C     BUOYANCY
      E(9)=RB*V(1)*KV
C     VORTICITY
      VF=VOLUME
      KK=1
      DO 110 I=1,K
      DO 110 J=1,L
      E(9+KK )=CS(I,J)*VOLUME
      VF=VF-E(KK+9)
  110 KK=KK+1
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```
C     VOLUME OF SOLID
C     VF-VOLUME OF THE FLUID PART OF WASTE MATERIAL
      T(1)=0.
      NE=9+K*L
C     NE-NO. OF TOTAL EQS
      IY=1
C     IY-INDEX OF DEPTH WHERE DENSITY SPECIFIED
      ISTEP=1
C     ISTEP-TIME STEP
      NC=K*L
C     NC IS EQN. NO. FOR SOLIDS
      NUTRL=0
C     NUTRL =1 INDICATE NEUTRAL POSITION REACHED
      IPLUNG=0
C     IPLUNG-INDICATOR OF HITTING BOTTOM
  111 CX(ISTEP)=E(1)
      CY(ISTEP)=E(2)
      CZ(ISTEP)=E(3)
      VOLUME=(E(4)+E(8))/ROA(1)
      CMMASS=1./(CM*E(4))
      U(ISTEP)=E(5)*CMMASS
      V(ISTEP)=E(6)*CMMASS
      W(ISTEP)=E(7)*CMMASS
      ENTRCO(ISTEP)=ALPHA
      IF (E(9).LE. 0) E(9)=0.
C     WHEN VORTICITY GOES TO ZERO, IT IS SET TO ZERO
      VORT(ISTEP)=E(9)
      BC(ISTEP)=(VOLUME*3./(2.*PAI))**.333333
C     BC-RADIUS OF CLOUD
      AA(ISTEP)=.5*BC(ISTEP)
      KK=1
      DO 120 I=1,K
      DO 120 J=1,L
      SS(KK,ISTEP)=E(9+KK)/VOLUME
  120 KK=KK+1
C     SS SOLID CONCENTRATION IN VOLUME RATIO
      FC(ISTEP)=VF/VOLUME
      ROO=E(4)/VOLUME
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA)*.51545
      IF((CY(ISTEP)+3.*BC(ISTEP)/8.) .GE. H) IPLUNG=1
      IF(IPLUNG .EQ. 1) GO TO 1000
      IF(NUTRL .EQ.  1)GO TO 1000
      IF(ISTEP .GE. 600) GO TO 1000
      CALL RUNGS(DERIVE1,NE)
      ISTEP=ISTEP+1
      T(ISTEP)=T(ISTEP-1)+DT
      GO TO 111
 1000 WRITE(6,22)IJK,DT,IPLUNG,NUTRL,ISTEP
   22 FORMAT(/5X,I5,E12.4,3I5)
      IF(ISTEP .LT. 100 .OR. ISTEP .GT. 200)210,220
  210 DT=DT*ISTEP*DINCR/150.
      IF(IJK.EQ. 5) GO TO 220
      GO TO 25
  220 CONTINUE
      IF(IPCN.EQ.0) GO TO 8001
      WRITE(6,13)
   13 FORMAT(// 8X,4HTIME,5X,1HX,7X,1HY,7X,1HZ,6X,1HU,6X,1HV,5X,1HW,6X,
     ,       7HDEN-DIF,3X,6HRADIUS,1X,5HVORT.,2X,5HALPHA,2X,
     ,      12HFLUID CONC. ,
     ,        10HSOLID-VOL.,2X,13HCONCENTRATION)
      DO 240 JJJ=1,ISTEP,NGRID
      DO 230 KK=1,NC
  230 ACONC(KK)=2.*PAI*BC(JJJ   )**3*SS(KK,JJJ)/3.
      WRITE(6,14)T(JJJ),CX(JJJ),CY(JJJ),CZ(JJJ),U(JJJ),V(JJJ),
     ,        W(JJJ),DENDIF(JJJ),BC(JJJ),VORT(JJJ),ENTRCO(JJJ),FC(JJJ),
     ,        ACONC(1),SS(1,JJJ)
   14 FORMAT( 4X,4F8.2,F6.2,F7.3,F6.2,E12.4,2F7.2,F7.4,3E12.4)
      IF(NC .EQ. 1) GO TO 240
      DO 231 KK=2,NC
  231 WRITE(6,15)ACONC(KK),SS(KK,JJJ)
   15 FORMAT(100X,2E12.4)
  240 CONTINUE
 8001 IF(IGCN.EQ.0) GO TO 8002
      ISTEP1=ISTEP+1
      T(ISTEP1)=2.*T(ISTEP)-T(ISTEP-1)
      CX(ISTEP1)=2.*CX(ISTEP)-CX(ISTEP-1)
      CZ(ISTEP1)=2.*CZ(ISTEP)-CZ(ISTEP-1)
      CY(ISTEP1)=0.
      BC(ISTEP1)=0.
      FC(ISTEP1)=0.
      CALL DRAW(T,T,T,T,CY,BC,CX,CZ       ,ISTEP1,1,NSCALE,4)
      IF(IGCN.EQ.1) GO TO 8002
      DO 8004 I=1,NC
      DO 8004 J=1,ISTEP
 8004 AUX(J,I)=SS(I,J)
      DO 8005 J=1,NC
 8005 AUX(ISTEP1,J)=0.
      NCP1=NC+1
      IF(NCP1.GT.4) NCP1=4
      CALL DRAW(T,T,T,T,FC,AUX(1,1),AUX(1,2),AUX(1,3),ISTEP1,16,NSCALE,
     *NCP1)
      IF(NC.LT.4) GO TO 8002
      NCM1=NC
      IF(NCM1.GT.4) GO TO 8006
      CALL DRAW(T,T,T,T,AUX(1,1),AUX(1,2),AUX(1,3),AUX(1,4),ISTEP1,10,
     *NSCALE,NCM1)
      GO TO 8002
 8006 CALL DRAW(T,T,T,T,AUX(1,1),AUX(1,2),AUX(1,3),AUX(1,4),ISTEP1,10,
     *NSCALE,4)
      NCM5=NCM1-4
      CALL DRAW(T,T,T,T,AUX(1,5),AUX(1,6),AUX(1,7),AUX(1,8),ISTEP1,11,
     *NSCALE,NCM5)
 8002 CONTINUE
      DT1=DT
      DO 300 KK=1,NC
      KKK=NC-KK+1
  300 E(KKK+10)=E(KKK+9)
      E(9)=BC(ISTEP)
      INDEX=ISTEP
      IF(IPLUNG .EQ. 1) GO TO 310
      E(10)=0.
      A0=.5*BC(ISTEP)
      RETURN
  310 E(10)=ROO*PAI*E(9)**3*(2.666666*V(ISTEP))/32.
      A0=   BC(ISTEP)
      IBFO=ISTEP
      RETURN
      END
vv
```

```
      SUBROUTINE JET
C     TIME LIMITED CONTINUOUS DISCHARGE THROUGH A NOZZLE UNDER A
C     MOVING BARGE
C
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON/AUXX/AUX(600,8)
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON             CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),DENDIF(600),   DL(600),
     ,  CZ(600),SS(8,600),SAVF(600),DUMY2(5,600),FC(600),T(600),
     ,     BC(600),WS(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,              UBX,WBZ,  V2,CMAX(9),YY
      COMMON /COMPUT/FE(7,151),F(20),ACONC(125),CS(4,2),
     ,DUMY4(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DS,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      NGRID=2
      IJK=0
      IBED=0
      ILEAVE=0
      WRITE(6,90051)
90051 FORMAT(     //10X,17HBARGE OPERATION 2/10X,
     ,        47HDISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE)
      READ(5,90001)TSTOP
      WRITE(6,90069)TSTOP
90069 FORMAT(/10X,5HTSTOP,E12.4,4HSEC./)
C     TIME LIMIT IN THE COMPUTATION
      READ(5,90002)ISIZE,KEY1,KEY2,KEY3
C     KEY1=1  USE TETRA TECH SUGGESTED COEFFICIENTS
C     KEY1=2  USE READ IN COEFFICIENTS
C     KEY2=1 COMPUTATION STOPS AT THE END OF JET PHASE
C     KEY2=2 COMPUTATION STOPS AT THE END OF DYNAMIC COLLAPSE
C     KEY2=3 COMPUTATION STOPS AT THE END OF LONG TERM DIFFUSION
C     KEY3=0 LONG TERM DIFFUSION FOR FLUID PART ALSO
C     KEY3=1 NO LONG TERM DIFFUSION FOR FLUID PART
      WRITE(6,90074)ISIZE,KEY1,KEY2,KEY3
90074 FORMAT(10X,15HGRID POINT SIZE,I5,5H KEY1,I5,5H KEY2,I5,5H KEY3,I5)
      GO TO (1,2)KEY1
    1 WRITE(6,90070)
90070 FORMAT(/10X,37HUSE TETRA TECH SUGGESTED COEFFICIENTS/)
      DINCR1=1.
      DINCR2=1.
      ALPHA1=0.0806
      ALPHA2=.3536
      BETA=0.
      CD=1.3
      GAMA=.25
      CDRAG=1.
      CFRIC=.01
      CD3=.2
      CD4=2.
      ALPHA3=.3536
      ALPHA4=.001
      FRICTN=.01
      F1=.1
      CM=1.
      ALFA1=1.
      ALFA2=1.
      GAMA1=0.
      GAMA2=0.
      ALAMDA=.001
      GO TO 3
    2 WRITE(6,90071)
90071 FORMAT(10X, 24HUSE READ IN COEFFICIENTS)
      READ(5,90001)DINCR1,DINCR2
      READ(5,90001)ALPHA1,ALPHA2,BETA,CD
90001 FORMAT(8G10.5)
C     ALPHA1-ENTRAINMENT COEF FOR JET
C     ALPHA2-ENTRAINMENT COEF FOR 2-D THERMAL
C     BETA-SETTLING COEF.
C     CD-DRAG COEF.
      READ(5,90001)GAMA,CDRAG,CFRIC,CD3,CD4,ALPHA3,ALPHA4,FRICTN,F1,CM
      READ(5,90001)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
    3 CONTINUE
      WRITE(6,90073)DINCR1,DINCR2
90073 FORMAT(10X,6HDINCR1,F10.4,7H DINCR2,F10.4)
      WRITE(6,90052)ALPHA1,ALPHA2,BETA,CD
90052 FORMAT(10X,6HALPHA1,F10.4,8H  ALPHA2,F10.4,6H  BETA,F10.4,
     ,              3H CD,F10.4)
      WRITE(6,90072)GAMA,CDRAG,CFRIC.CD3,CD4,ALPHA3,ALPHA4,FRICTN,F1,CM
90072 FORMAT( 9X,5H GAMA,F5.2,6H CDRAG,F5.2,6H CFRIC, F5.3,4H CD3,F5.2,
     ,   4H CD4,F5.2,7H ALPHA3,F10.4,
                                /9X,7H ALPHA4,F10.4,7H FRICTN,F10.4,
     ,
     ,      3H F1,F10.4,3H CM,F10.4)
      WRITE(6,90068)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
90068 FORMAT(10X,5HALFA1,F10.4,6H ALFA2,F10.4,6H GAMA1,F10.4,
     ,     6H GAMA2,F10.4,/9X,7H ALAMDA,F10.4/)
      READ(5,90001)BC(1),ROO,THETA2(1),U(1),CY(1)
      WRITE(6,90053)BC(1),ROO,THETA2(1),U(1),CY(1)
90053 FORMAT(10X,12HJET RADIUS  ,F10.4,9H  DENSITY,F10.4,
                14H  ANGLE OF JET,F10.4,/10X,8HVELOCITY,F10.4,
     ,
     ,   3H AT,F10.4,4H FT.)
      READ(5,90002) K,L
90002 FORMAT(8I10)
C     K-NO. OF DIFFERENT DENSITY
C     L-NO. OF DIFFERENT FALL VEL.
      WRITE(6,90054)K,L
90054 FORMAT(15X,3H  K,I5,3H  L ,I5)
      READ(5,90001)(ROAS(I),I=1,K)
      READ(5,90001)((CS(I,J),J=1,L),I=1,K)
      READ(5,90001)((WS(I,J),J=1,L),I=1,K)
      DO 15 I=1,K
      WRITE(6,90055)ROAS(I)
90055 FORMAT(10X, 16HDENSITY OF SOLID,8X,F12.4)
      WRITE(6,90056)(CS(I,J   ),J=1,L)
90056 FORMAT(10X,13HCONCENTRATION,11X,8E12.4)
      WRITE(6,90057)(WS(I,J),J=1,L)
90057 FORMAT(10X,22HFALL VELOCITY OF SOLID,2X,8E12.4)
   15 CONTINUE
      READ(5,90001)UB,SAI,TIME
C     SAI IS LIMITED TO 180-270 DEGREES
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      WRITE(6,90058)UB,SAI,TIME
90058 FORMAT(10X,14HBARGE VELOCITY,F10.4,18H ANGLE WITH X-AXIS,F10.4,
     ,      8H DEGREES,4H FOR,E10.4,5H SEC.)
      DO 20 I=1,K
   20 ROAS(I)=ROAS(I)*1.94
      ROO=ROO*1.94
      SAII=SAI
      SAI=SAI*PAI*.005555556
      UBX=UB*COS(SAI)
      WBZ=UB*SIN(SAI)
      IF(SAII .EQ. 180.)WBZ=0.
      IF(SAII .EQ. 270.)UBX=0.
      U1=UA0-UBX
      U2=U1
      U3=-UBX
      U4=-UBX
      W1=-WBZ
      W2=WA0-WBZ
      W3=-WBZ
      W4=-WBZ
      WRITE(6,90059)
90059 FORMAT(/10X,45HAMBIENT CURRENT FOR A MOVING COORDINATE FIXED,
     ,            13H ON THE BARGE)
      WRITE(6,90060)
90060 FORMAT(11X,4X,1H0,6X,2HYU,6X,2HYW,6X,2HYE,6X,1HH)
      WRITE(6,90061)U1,U2,U3,U4
90061 FORMAT(11X,2F8.4,8X,2F8.4)
      WRITE(6,90062)W1,W2,W3,W4
90062 FORMAT(11X,F8.4,8X,3F8.4)
      ROAA=ROA(1)
      NC=K*L
C     NC IS EQN. NO. FOR SOLIDS
      NE=8+K*L
C     NE-NO. OF TOTAL EQS
      E(1)=0.
      E(2)=CY(1)
      E(3)=0.
      SAI=SAI-PAI
C     SAI IS ANGLE OF INJECTION JET
      THETA2(1)=THETA2(1)*PAI*0.005555556
      DUM=SIN(THETA2(1))*COS(SAI)
      IF(ABS(DUM) .GE. 1.0)DUM=ABS(DUM)/DUM
      THETA1=ACOS(DUM)
      DUM=SIN(THETA2(1))*SIN(SAI)
      IF(ABS(DUM) .GE. 1.0)DUM=ABS(DUM)/DUM
      THETA3=ACOS(DUM)
      FLUX=PAI*BC(1)**2*U(1)
      E(4)=ROO*FLUX
      F4U=E(4)*U(1)
      E(5)=F4U*COS(THETA1)
      E(6)=F4U*COS(THETA2(1))
      E(7)=F4U*COS(THETA3)
      E(8)=(ROA(1)-ROO)*FLUX
      IF(SAII .EQ. 180.)E(7)=0.
      IF(SAII .EQ. 270.)E(5)=0.
      CF=1.
      KK=1
      DO 30 I=1,K
      DO 30 J=1,L
      E(8+KK)=FLUX*CS(I,J)
      CF=CF-CS(I,J)
C     FLUID CONCENTRATION AT THE BEGINNING
   30 KK=KK+1
      DINCR=DINCR1
      DO 31 JJ=1,NE
   31 SAVF(JJ)=E(JJ)
      WRITE(6,1973)
 1973 FORMAT(1H1,10X,15HJET CONVECTION /)
   25 DO 26 JJ=1,NE
   26 E(JJ)=SAVF(JJ)
      DS=DINCR*BC(1)
      DSAVE=20.*DS
      IJK=IJK+1
      T(1)=0.
      S(1)=0.
      IY=1
C     IY-INDEX OF DEPTH WHERE DENSITY SPECIFIED
      ISTEP=1
C     ISTEP-COMPUTATION STEP
      NOTE=0
C     NOTE - INDICATE HITTING BOTTOM
      NUTRL=0
C     NUTRL - FIRST HORIZONTAL POSITION REACHED
  100 CX(ISTEP)=E(1)
      CY(ISTEP)=E(2)
      CZ(ISTEP)=E(3)
      U(ISTEP)=SQRT(E(5)**2+E(6)**2+E(7)**2)/E(4)
      BC(ISTEP)=SQRT((E(4)+E(8))/(ROA(1)*U(ISTEP)*PAI))
      AA(ISTEP)=BC(ISTEP)
      FLUX=U(ISTEP)*PAI*BC(ISTEP)**2
      ROO=E(4)/FLUX
      DUM=E(6)/(E(4)*U(ISTEP))
      IF(ABS(DUM) .GE. 1.0)DUM=ABS(DUM)/DUM
      THETA2(ISTEP) =ACOS(DUM)
      DUM=E(5)/(E(4)*U(ISTEP))
      IF(ABS(DUM) .GE. 1.0) DUM=ABS(DUM)/DUM
      VS=SIN(THETA2(ISTEP))
      IF(VS .LT. .001) GO TO 101
      ZETA=DUM/VS
      IF(ABS(ZETA) .GE. 1.0) ZETA=ABS(ZETA)/ZETA
      CZETA(ISTEP) =ZETA
      ZETA=ACOS(ZETA)
      SZETA(ISTEP)=SIN(ZETA)
      GO TO 102
  101 CZETA(ISTEP)=1.
      SZETA(ISTEP)=0.
  102 CONTINUE
      DL(ISTEP)=DS*VS
      KK=1
      DO 110 I=1,K
      DO 110 J=1,L
      SS(KK ,ISTEP)=E(8+KK)/FLUX
  110 KK=KK+1
      FC(ISTEP)=CF*BC(1)**2*U(1)/(BC(ISTEP)**2*U(ISTEP))
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA)*.51545
      IF((CY(ISTEP)+.85*BC(ISTEP)*SIN(THETA2(ISTEP))) .GE. H)  NOTE=1
      IF(ISTEP .EQ. 1) GO TO 103
      IF(CY(ISTEP) .LE. CY(ISTEP-1))NUTRL=1
      IF(NUTRL  .EQ. 1) GO TO 200
      IF(ISTEP .GE. 600) GO TO 200
      IF(NOTE .EQ. 1) GO TO 200
  103 CALL RUNGS(DERIVF3,NE)
      DS=DS*1.1
      IF(DS.GT.DSAVE) DS=DSAVE
      DT= DS/U(ISTEP)
      ISTEP=ISTEP+1
      T(ISTEP)=T(ISTEP-1)+DT
      S(ISTEP)=S(ISTEP-1)+DS
      GO TO 100
  200 WRITE(6,90066)IJK,DINCR,BC(1),NOTE,NUTHL,ISTEP
90066 FORMAT(/1X,I5,2E12.4,3I5/)
      IF(IJK .EQ. 5) GO TO 220
      IF(ISTEP .LT. 100 .OR. ISTEP .GT. 190) 210,220
  210 DINCR=DINCR*ISTEP/140.
      GO TO 25
  220 CONTINUE
      IF(IPCN.EQ.0) GO TO 8001
      WRITE(6,90063)
90063 FORMAT(13X, 1HT,8X,1HS,8X,1HX,8X,1HY,8X,1HZ,8X,1HU,3X,6HRADIUS,4X,
     ,7HDEN-DIF,2X,12H FLUID CONC.,13HFLUX OF SOLID,2X,13HCONCENTRATION)
      DO 240 JJJ=1,ISTEP,NGRID
      DO 230 KK=1,NC
  230 ACONC(KK)=    PAI*BC(JJJ)**2*SS(KK,JJJ)* U(JJJ)
      WRITE(6,90064)T(JJJ),S(JJJ),CX(JJJ),CY(JJJ),CZ(JJJ),U(JJJ),
     ,     BC(JJJ),DENDIF(JJJ),FC(JJJ),ACONC(1),SS(1,JJJ)
90064 FORMAT(8X,5F9.2,2F8.3,4E12.4)
      IF(NC .EQ. 1) GO TO 240
      DO 201 KK=2,NC
  201 WRITE(6,90065)ACONC(KK),SS(KK,JJJ)
90065 FORMAT(93X,2E12.4)
  240 CONTINUE
 8001 IF(IGCN.EQ.0) GO TO 8002
      ISTEP1=ISTEP+1
      CX(ISTEP1)=2.*CX(ISTEP)-CX(ISTEP-1)
      CZ(ISTEP1)=2.*CZ(ISTEP)-CZ(ISTEP-1)
      CY(ISTEP1)=0.
      BC(ISTEP1)=0.
      FC(ISTEP1)=0.
      CALL DRAW(CX,CX,CX,CX,CY,BC,FC,CZ       ,ISTEP1,3,NSCALE,4)
      IF(IGCN.EQ.1) GO TO 8002
      DO 8004 I=1,NC
      DO 8004 J=1,ISTEP
 8004 AUX(J,I)=SS(I,J)
      ISTEP1=ISTEP+1
      DO 8005 J=1,NC
 8005 AUX(ISTEP1,J)=0.
      NCCC=NC
      IF(NCCC.GT.4) NCCC=4
      CALL DRAW(CX,CX,CX,CX,AUX(1,1),AUX(1,2),AUX(1,3),AUX(1,4),ISTEP1,
     * 10,NSCALE,NCCC)
      IF(NC.LE.4) GO TO 8002
      NCM4=NC-4
      CALL DRAW(CX,CX,CX,CX,AUX(1,5),AUX(1,6),AUX(1,7),AUX(1,8),ISTEP1,
     * 11,NSCALE,NCM4)
 8002 CONTINUE
      DO 400 KK=1,NC
      KKK=NC-KK+1
  400 E(KKK+10)=E(KKK+8)
      UU=1./U(ISTEP)
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      DO 401 KK=4,8
  401 E(KK)=E(KK)*UU
      DO 402 KK=1,NC
  402 E(10+KK)=E(10+KK)*UU
      V2=U(ISTEP)*COS(THETA2(ISTEP))
      E(9)=BC(ISTEP)
      VF=CF*BC(1)**2*U(1)/(BC(ISTEP)**2*U(ISTEP))
C     FLUID CONCENTRATION AT THE END OF JET
      IF(NOTE .EQ. 1)GO TO 410
      E(10)=0.
      A0=BC(ISTEP)
      RETURN
  410 E(10)=(PAI*.25*V2*BC(ISTEP)**2*ROO))
      A0=BC(ISTEP)*2.
      IEND=ISTEP
      RETURN
      END
vv
```

```
      SUBROUTINE WAKE
C     WASTE MATERIAL DISCHARGED INTO THE BARGE WAKE
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,               YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),DENDIF(600),   DL(600),
     ,  CZ(600),SS(8,600),SAVE(600),DUMY2(5,600),FC(600),T(600),
     ,     BC(600),WS(4,2),
     ,       ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,               UBX,WBZ,  V2,CMAX(9),YY
      COMMON /COMPUT/EE(7,151),E(20),ACONC(123),CS(4,2),
     ,DUMY4(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,               CCMAX(151),VAR(151)
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DS,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/AUXX/AUX(600,8)
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      NGRID=2
      IJK=0
      INDEX=0
      IBED=0
      ILEAVE=0
      WRITE(6,90051)
90051 FORMAT(     /10X,17HBARGE OPERATION 3 //10X,
     , 62HWASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
     ,/10X,56HAFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
     , /10X,41HTO BE IN A FORM OF HALF CYLINDER THERMAL.  /)
      READ(5,90001)TSTOP
      WRITE(6,90069)TSTOP
90069 FORMAT(/10X,5HTSTOP,E12.4,4HSEC./)
C     TIME LIMIT IN THE COMPUTATION
      READ(5,90002)ISIZE,KEY1,KEY2,KEY3
C     KEY1=1  USE TETRA TECH SUGGESTED COEFFICIENTS
C     KEY1=2  USE READ IN COEFFICIENTS
C     KEY2=1 COMPUTATION STOPS AT THE END OF CONVECTIVE DESCENT
C     KEY2=2 COMPUTATION STOPS AT THE END OF DYNAMIC COLLAPSE
C     KEY2=3 COMPUTATION STOPS AT THE END OF LONG TERM DIFFUSION
C     KEY3=0 LONG TERM DIFFUSION FOR FLUID PART ALSO
C     KEY3=1 NO LONG TERM DIFFUSION FOR FLUID PART
      WRITE(6,90074)ISIZE,KEY1,KEY2,KEY3
90074 FORMAT(10X,15HGRID POINT SIZE,I5,5H KEY1,I5,5H KEY2,I5,5H KEY3,I5)
      GO TO (1,2)KEY1
    1 WRITE(6,90070)
90070 FORMAT(/10X,37HUSE TETRA TECH SUGGESTED COEFFICIENTS/)
      C1=.6
      C2=4.
      DINCR1=.25
      DINCR2=1.
      ALPHA=0.3536
      ALPHA1=0.0806
      BETA=0.
      CD1=.5
      CD2=1.3
      CM=1.
      GAMA=.25
      CDRAG=1.
      CFRIC=.01
      CD3=.2
      CD4=2.
      ALPHA3=.3556
      ALPHA4=.001
      FRICTN=.01
      F1=.1
      ALFA1=1.
      ALFA2=1.
      GAMA1=0.
      GAMA2=0.
      ALAMDA=.001
      GO TO 3
    2 WRITE(6,90071)
90071 FORMAT(10X, 24HUSE READ IN COEFFICIENTS)
      READ(5,90001)C1,C2
      READ(5,90001)DINCR1,DINCR2
      READ(5,90001)ALPHA,BETA,CD1,CD2,CM,ALPHA1
90001 FORMAT(8G10.4)
C     ALPHA =ENTRAINMENT COEF FOR 2-D THERMAL
C     BETA=SETTLING COEF.
C     CD1 =DRAG COEF. OF A HALF SPHERE WEDGE
C     CD2=DRAG COEF. FOR CYLINDER
C     CM = ADDED MASS COEF.
      READ(5,90001)GAMA,CDRAG,CFRIC,CD3,CD4,ALPHA3,ALPHA4,FRICTN,F1
      READ(5,90001)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
    3 CONTINUE
      WRITE(6,90073)DINCR1,DINCR2
90073 FORMAT(10X,6HDINCR1,F10.4,7H DINCR2,F10.4)
      WRITE(6,90067)C1,C2
90067 FORMAT(/9X,20H BARGE SHAPE FACTORS,3H C1,F5.2,3H C2,F5.2)
      WRITE(6,90052)ALPHA,BETA,CD1,CD2,CM
90052 FORMAT(10X,6HALPHA ,F10.4,5H BETA,F10.4,4H CD1,F10.4,4H CD2,F10.4,
     ,   3H CM, F10.4)
      WRITE(6,90072)GAMA,CDRAG,CFRIC,CD3,CD4,ALPHA3,ALPHA4,FRICTN,F1
     * ,ALPHA1
90072 FORMAT( 9X,5H GAMA,F5.2,6H CDRAG,F5.2,6H CFRIC, F5.3,4H CD3,F5.2,
     ,   4H CD4,F5.2,7H ALPHA3,F10.4,
     ,                            /9X,7H ALPHA4,F10.4,7H FRICTN,F10.4,
     ,      3H F1,F10.4,7H ALPHA1,F10.4)
      WRITE(6,90068)ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA
90068 FORMAT(10X,5HALFA1,F10.4,6H ALFA2,F10.4,6H GAMA1,F10.4,
     ,    6H GAMA2,F10.4,/9X,7H ALAMDA,F10.4/)
      READ(5,90001) ROO,QD,BB,DD
      WRITE(6,90053)ROO,QD,BB,DD
90053 FORMAT(10X,8H DENSITY,F10.4,15H DISCHARGE RATE,F10.4,
     ,  12H BARGE WIDTH,F10.2,12H BARGE DEPTH,F10.2)
      READ(5,90002) K,L
90002 FORMAT(8I10)
C     K=NO. OF DIFFERENT DENSITY
C     L=NO. OF DIFFERENT FALL VEL.
      WRITE(6,90054)K,L
90054 FORMAT(15X,3H  K,I5,3H  L ,I5)
      READ(5,90001)(ROAS(I),I=1,K)
      READ(5,90001)((CS(I,J),J=1,L),I=1,K)
      READ(5,90001)((WS(I,J),J=1,L),I=1,K)
      DO 15 I=1,K
      WRITE(6,90055)ROAS(I)
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```
90055 FORMAT(10X, 16HDENSITY OF SOLID,8X,F12.4)
      WRITE(6,90056)(CS(I,J  ),J=1,L)
90056 FORMAT(10X,13HCONCENTRATION,11X,8E12.4)
      WRITE(6,90057)(WS(I,J),J=1,L)
90057 FORMAT(10X,22HFALL VELOCITY OF SOLID,2X,8E12.4)
   15 CONTINUE
      READ(5,90001)UB,SAI,TIME
C     SAI IS LIMITED TO 180-270 DEGREES
      WRITE(6,90058)UB,SAI,TIME
90058 FORMAT(/10X,14HBARGE VELOCITY,F10.4,18H ANGLE WITH X-AXIS,F10.4,
     ,      8H DEGREES,4H FOR,F10.4,5H SEC.)
      DO 20 I=1,K
   20 ROAS(I)=ROAS(I)*1.94
      ROO=ROO*1.94
      SAII=SAI
      SAI=SAI*PAI*.005555556
      UBX=UB*COS(SAI)
      WBZ=UB*SIN(SAI)
      IF(SAII .EQ. 180.)WBZ=0.
      IF(SAII .EQ. 270.)UBX=0.
      U1=UA0-UBX
      U2=U1
      U3=-UBX
      U4=-UBX
      W1=-WBZ
      W2=WA0-WBZ
      W3=-WBZ
      W4=-WBZ
      WRITE(6,90059)
90059 FORMAT(/10X,45HAMBIENT CURRENT FOR A MOVING COORDINATE FIXED,
     ,          13H ON THE BARGE)
      WRITE(6,90060)
90060 FORMAT(11X,4X,1H0,6X,2HYU,6X,2HY*,6X,2HYE,6X,1HH)
      WRITE(6,90061)U1,U2,U3,U4
90061 FORMAT(9X,3H UA,2F8.3,8X,2F8.3)
      WRITE(6,90062)W1,W2,W3,W4
90062 FORMAT(9X,3H WA,F8.3,8X,3F8.3)
C-----------------------------------------
      RR=SQRT(BB*DD*.5)
      ANGLE1=ATAN(W1,U1)
      ANGLE2=SAI-PAI-ANGLE1
      VB=SQRT(U1**2+W1**2)*COS(ANGLE2)
C     VB=AMBIENT VELOCITY IN THE BARGE DIRECTION
      C3=1./(C1*C2**.333333)
      BC(1)=2.*RR/C3
      FLUX=.5*PAI*BC(1)**2*VB*.75
      CF=1.
      DO 21 I=1,K
      DO 21 J=1,L
      CF=CF-CS(I,J)
C     CONCENTRATION OF FLUID
   21 CS(I,J)=CS(I,J)*QD/FLUX
      CF=CF*QD/FLUX
      ROU=ROO
      DINCR=DINCR1
C     INCREMENT IN DS = DINCR*BC(1)
C-----------------------------------------
      WRITE(6,1973)
 1973 FORMAT(1H1,10X,18HCONVECTIVE DESCENT,/)
   25 ROO=(ROU*QD+(FLUX-QD)*ROA(1))/FLUX
```

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      ROAA=ROA(1)
      IJK=IJK+1
      DS=DINCR*BC(1)
      E(1)=0.
      E(2)=4.*BC(1)/(3.*PAI)
      E(3)=0.
      THETA2(1)=.5*PAI
      E(4)=ROO*.5*PAI*BC(1)**2*DS
      E4CM=E(4)*CM
      E(5)=E4CM*COS(SAI-PAI)*.750*VB
      E(6)=0.
      E(7)=E4CM*SIN(SAI-PAI)*.750*VB
      E(8)=(ROA(1)-ROO)*.5*PAI*BC(1)**2*DS
      IF(SATI .EQ. 180.)E(7)=0.
      IF(SATI .EQ. 270.)E(5)=0.
      KK=1
      DO 30 I=1,K
      DO 30 J=1,L
      E(8+KK)=.5*PAI*BC(1)**2*CS(I,J)*DS
   30 KK=KK+1
      VF=CF*.5*PAI*BC(1)**2*DS
C     VOLUME OF FLUID
      T(1)=0.
      S(1)=0.
      NE=8+K*L
C     NE=NO. OF TOTAL EQS
      IY=1
C     IY=INDEX OF DEPTH WHERE DENSITY SPECIFIED
      ISTEP=1
C     ISTEP=COMPUTATION STEP
      NC=K*L
C     NC IS EQN. NO. FOR SOLIDS
      NUTRL=0
C     NUTRL =NUTRAL BUOYANT POSITION REACHED
      NOTE=0
C     NOTE =INDICATOR OF HITTING BOTTOM
C-------------------------------------------------
  100 CX(ISTEP)=E(1)
      CY(ISTEP)=E(2)
      CZ(ISTEP)=E(3)
      CMMASS=1./(CM*E(4))
      V1=E(5)*CMMASS
      V2=E(6)*CMMASS
      V3=E(7)*CMMASS
      U(ISTEP)=SQRT(V1**2+V2**2+V3**2)
      UU=   SQRT(V1**2+V3**2)
      IF(ISTEP .EQ. 1)111,112
  111 DL(ISTEP)=DS
      DLDT=0.
      GO TO 113
  112 DL(ISTEP)=UU*DL(ISTEP-1)/UUU
      DLDT=(DL(ISTEP)-DL(ISTEP-1))*UUU/DL(ISTEP-1)
  113 VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/ VOLUME
      AREA=VOLUME/DL(ISTEP)
      BC(ISTEP)=SQRT(2.*AREA/PAI)
      AA(ISTEP)=.5*BC(ISTEP)
      THETA2(ISTEP)=.5*PAI
      DS=U(ISTEP)*DL(ISTEP)/UU
      UUU=UU
      UU=1./UU
      SZETA(ISTEP)=V3*UU
      CZETA(ISTEP)=V1*UU
C     SIN AND COS OF ZETA
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA)*.51545
      KK=1
      DO 110 I=1,K
      DO 110 J=1,L
      SS(KK ,ISTEP)=E(8+KK)/VOLUME
  110 KK=KK+1
      FC(ISTEP)=VF/VOLUME
      IF((CY(ISTEP)+BC(ISTEP)*.425)                    .GE. H)NOTE=1
      IF(NOTE    .EQ. 1) GO TO 200
      IF(ISTEP .GE. 600) GO TO 200
      IF(NUTRL .EQ. 1) GO TO 200
      CALL RUNGS(DERIVES,NE)
      DT= DS/U(ISTEP)
      ISTEP=ISTEP+1
      T(ISTEP)=T(ISTEP-1)+DT
      S(ISTEP)=S(ISTEP-1)+DS
      GO TO 100
  200 WRITE(6,90066)IJK,DINCR,BC(1),NOTE,NUTRL,ISTEP
90066 FORMAT(/1X,I5,2E12.4,3I5/)
      IF(IJK .EQ. 5) GO TO 220
      IF(ISTEP .LT. 100 .OR. ISTEP .GT. 190) 210,220
  210 DINCR=DINCR*ISTEP/140.
      GO TO 25
  220 CONTINUE
      IF(IPCN.EQ.0) GO TO 8001
      WRITE(6,90063)
90063 FORMAT(13X, 1HT,8X,1HS,8X,1HX,8X,1HY,8X,1HZ,8X,1HU,3X,6HRADIUS,4X,
     ,7HDEN-DIF,2X,12H FLUID CONC.,13H  SOLID VOL. ,2X,13HCONCENTRATION)
      DO 240 JJJ=1,ISTEP,NGRID
      DO 230 KK=1,NC
  230 ACONC(KK)=.5*PAI*BC(JJJ)**2*SS(KK,JJJ)*DL(JJJ)
      WRITE(6,90064)T(JJJ),S(JJJ),CX(JJJ),CY(JJJ),CZ(JJJ),U(JJJ),
     ,    BC(JJJ),DENDIF(JJJ),FC(JJJ),ACONC(1),SS(1,JJJ)
90064 FORMAT(8X,5F9.2,2F8.3,4E12.4)
      IF(NC .EQ. 1) GO TO 240
      DO 201 KK=2,NC
  201 WRITE(6,90065)ACONC(KK )   ,SS(KK,JJJ)
90065 FORMAT(93X,2E12.4)
  240 CONTINUE
 8001 IF(IGCN.EQ.0) GO TO 8002
      ISTEP1=ISTEP+1
      CX(ISTEP1)=2.*CX(ISTEP)-CX(ISTEP-1)
      CZ(ISTEP1)=2.*CZ(ISTEP)-CZ(ISTEP-1)
      CY(ISTEP1)=0.
      BC(ISTEP1)=0.
      FC(ISTEP1)=0.
      CALL DRAW(CX,CX,CX,CX,CY,BC,FC.CZ       ,ISTEP1,3,NSCALE,4)
      IF(IGCN.EQ.1) GO TO 8002
      DO 8004 I=1,NC
      DO 8004 J=1,ISTEP
 8004 AUX(J,I)=SS(I,J)
      ISTEP1=ISTEP+1
      DO 8005 J=1,NC
 8005 AUX(ISTEP1,J)=0.
      NCCC=NC
      IF(NCCC.GT.4) NCCC=4
      CALL DRAW(CX,CX,CX,CX,AUX(1,1),AUX(1,2),AUX(1,3),AUX(1,4),ISTEP1,
     * 10,NSCALE,NCCC)
      IF(NC.LE.4) GO TO 8002
      NCM4=NC-4
      CALL DRAW(CX,CX,CX,CX,AUX(1,5),AUX(1,6),AUX(1,7),AUX(1,8),ISTEP1,
     * 11,NSCALE,NCM4)
 8002 CONTINUE
      INDEX=ISTEP
      DO 301 KK=4,NE
  301 E(KK)=E(KK)/DL(ISTEP)
      DO 300 KK=1,NC
      KKK=NC-KK+1
  300 E(KKK+10)=E(KKK+8)
      E(9)=BC(ISTEP)
      IF(NOTE    .EQ. 1) GO TO 310
      E(10)=0.
      A0=.5*BC(ISTEP)
      RETURN
  310 E(10)=(PAI*.25*V2        *BC(ISTEP)**2*ROU)
      A0=BC(ISTEP)
      IBED=ISTEP
      RETURN
      END
VV
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      SUBROUTINE COLAPS1
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YF,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),AA    (600),U(600),
     ,    V(600),     W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,CZ(600),SS(8,600),SAVF(600),DUMY2(6,600),FC(600),BC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /COMPUT/EE(7,151),E(20),ACONC(123),CS(4,2),
     ,    D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON/AUXX/AUX(600,8)
C
C
      DINCR=DINCR2
      IJK=0
      ALPHA=0.
      NOTRN=0
      IF(ISTEP .EQ. IBED)2,3
    3 E1=(ROA(IY+1)-ROA(IY))/(ROA(1)*(Y(IY+1)-Y(IY)))
      EG=SQRT(E1*G)
      B1=(BC(INDEX)**3*.84*EG*1000.)**.42857
      DT2=.001*(B1/BC(INDEX))**3/EG*.1
      DT=DT2
      GO TO 4
    2 DT=DT1
    4 CONTINUE
      WRITE(6,1)
    1 FORMAT(1H1,////10X,14HCOLLAPSE PHASE)
      NC=K*L
C     NC IS EQN. NO. FOR SOLIDS
      NE=NC+10
      DO 100 KK=1,NE
  100 SAVE(KK)=E(KK)
   25 DO 101 KK=1,NE
  101 E(KK)=SAVE(KK)
      IJK=IJK+1
      ISTEP=INDEX
      VOLUME=(F(4)+F(8))/ROA(1)
      ROU=F(4)/VOLUME
      NUTRL=0
C     NUTRL=3 DIFFUSION TAKES OVER DYNAMIC COLLAPSE
      IPLUNG=0
      IF(ISTEP .EQ. IBED )IPLUNG=1
C     IPLUNG=INDICATOR OF HITTING BOTTOM
      IF(ISTEP .EQ. IBED )GO TO 1500
      IF(ISTEP .EQ. INDEX) GO TO 122
  111 CX(ISTEP)=F(1)
      CY(ISTEP)=F(2)
      CZ(ISTEP)=E(3)
      VOLUME=(F(4)+F(8))/ROA(1)
      CMMASS=1./(CM*E(4))
      AA(ISTEP)=3.*VOLUME/(4.*PAI*E(9)**2)
C     AA=MINOR RADIUS
      BC(ISTEP)=E(9)
C     BC=MAJOR RAIUS OF CLOUD
      U(ISTEP)=E(5)*CMMASS
      V(ISTEP)=E(6)*AA(ISTEP)*CMMASS/BC(ISTEP)
      W(ISTEP)=E(7)*CMMASS
      ROO=E(4)/VOLUME
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA) .51545
      KK=1
      DO 120 I=1,K
      DO 120 J=1,L
      SS(KK,ISTEP)=E(10+KK)/VOLUME
  120 KK=KK+1
C     SS SAVE SOLID CONCENTRATION FOR DIFFUSION
      FC(ISTEP)=VF/VOLUME
      IF (IPLUNG .EQ. 4) GO TO 5
      IF((CY(ISTEP)+3.*2.*AA(ISTEP)/8.) .GE. H) IPLUNG=2
    5 AKX=2.*ALAMDA*(.5*E(9))**.333333
C     AKX = CHANGE OF B BY DIFFUSION
      BBDT=(BC(ISTEP)-BC(ISTEP-1))/DT
      IF(CY(ISTEP)-AA(ISTEP).LE.0.) GO TO 420
      IF(ISTEP .LE. INDEX+5) GO TO 121
      IF(AKX .GE. BBDT)NUTRL=3
  121 IF(NUTRL .EQ. 3) GO TO 2000
      IF (IPLUNG .EQ. 2) GO TO 1000
      IF(ISTEP .GE. 599) GO TO 2000
  122 CALL RUNGS(DERIVE2,NE)
      ISTEP=ISTEP+1
      T(ISTEP)=T(ISTEP-1)+DT
      GO TO 111
 1000 IBED=ISTEP
      DBT=E(10)*16./(PAI*AA(ISTEP)*BC(ISTEP)**2*ROO)
      E(10)=ROO*PAI*AA(ISTEP)*BC(ISTEP)**2
     ,      *(DBT+.6666667*BC(ISTEP)*V(ISTEP)/AA(ISTEP))/ 8.
      A0=A0*2.
 1500 CALL BOTTOM1
      IF(ISTEP .GE. 600) GO TO 2050
      IF(NUTRL .EQ. 3) GO TO 2000
      IF(IPLUNG .EQ. 4)1600,1500
 1600 E(6)=CM*E(4)*V(ISTEP)
      ROO=ROA(1)*E(4)/(E(4)+E(8))
      DBT=E(10)* 8./(PAI*AA(ISTEP)*BC(ISTEP)**2*ROO)
      E(10)=ROO*PAI*AA(ISTEP)*BC(ISTEP)**2*DBT/16.
      A0=A0*.5
      ILEAVE=ISTEP
      NOTRN =1
      GO TO 122
 2050 ISTEP=ISTEP-1
 2000 WRITE(6,22)IJK,DT,IPLUNG,NUTRL,ISTEP
   22 FORMAT(1X,I5,E12.4,3I5)
      IF((ISTEP-INDEX) .LE. 100 .OR. (ISTEP-INDEX) .GE. 399) 410,420
  410 DT=DT*(ISTEP-INDEX)*DINCR/250.
      IF(IJK .GE. 5) GO TO 420
      GO TO 25
  420 CONTINUE
      IF(IPCL.EQ.0) GO TO 8001
      WRITE(6,13)
 13 FORMAT(/ 3X,4HTIME,8X,1HX,9X,1HY,9X,1HZ,6X,1HU,6X,1HV,5X,1HW,
   ,        6X,7HDEN-DIF,5X,1HA,9X,1HB,5X,11HFLUID CONC., 3X,
   ,          10HSOLID-VOL.,2X,13HCONCENTRATION)
    NGRID=(ISTEP-INDEX)/100
    IF(NGRID .LT. 1) NGRID=1
    DO 430 JJJ=INDEX,ISTEP,NGRID
    DO 442 KK=1,NC
442 ACONC(KK)=4.*PAI*AA(JJJ)*BC(JJJ)**2*SS(KK,JJJ)/3.
    WRITE(6,14)T(JJJ),CX(JJJ),CY(JJJ),CZ(JJJ),U(JJJ),V(JJJ),
   ,       W(JJJ),DENDIF(JJJ),         AA(JJJ),BC(JJJ),FC(JJJ),ACONC(1),
   ,       SS(1,JJJ)
 14 FORMAT( 1X,2F10.2,F8.2,G11.4,F6.2,F7.3,F6.2,E12.4,F7.2,G11.4,
   ,        3F12.4)
    IF(NC .EQ. 1) GO TO 430
    DO 450 KK=2,NC
450 WRITE(6,15)ACONC(KK),SS(KK,JJJ)
 15 FORMAT(101X,2E12.4)
430 CONTINUE
8001 IF(IGCL.EQ.0) GO TO 8002
    ISTEP1=ISTEP+1
    T(ISTEP1)=2.*T(ISTEP)-T(ISTEP-1)
    AA(ISTEP1)=0.
    CY(ISTEP1)=0.
    BC(ISTEP1)=0.
    CX(ISTEP1)=2.*CX(ISTEP)-CX(ISTEP-1)
    CZ(ISTEP1)=2.*CZ(ISTEP)-CZ(ISTEP-1)
    CALL DRAW(T,T,T,T,AA,BC,CX,CY       ,ISTEP1,2,NSCALE,4)
    CALL DRAW(CX,T,T,T,CZ,T,T,T,ISTEP1,15,NSCALE,1)
8002 CONTINUE
    DT2=DT
    DO  140 KK=1,NC
    CMAX(KK)=SS(KK,ISTEP)
140 CONTINUE
    CMAX(NC+1)=FC(ISTEP)
C      FOR LONG TERM DIFFUSION USE
    IF(WS(1,1) .EQ. 0.)CMAX(1)=CMAX(2)
    A0=AA(ISTEP)
    YY=E(2)
    IF(CY(ISTEP)-AA(ISTEP).LE.0.) YY=AA(ISTEP)
    RETURN
    END
vv
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      SUBROUTINE COLAPS2
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON/AUXX/AUX(600,8)
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON /A/ EP(20)
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON        CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),  AA(600),DENDIF(600),   DL(600),
     ,  CZ(600),SS(8,600),SAVE(600),DUMY2(5,600),FC(600),T(600),
     ,    BC(600),WS(4,2),
     ,      ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,  V2,CMAX(9),YY
      COMMON /TORS/ DS,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /COMPUT/EF(7,151),E(20),ACONC(123),CS(4,2),
     ,   D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,IT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      DSS=DL(ISTEP)
      IF(METHOD .EQ. 2) AA(ISTEP)=BC(ISTEP)
      FV=VF
      IJK=0
      DINCR=DINCR2
      NGRID =2
      WRITE(6,90051)
90051 FORMAT(1H1,///10X,27HCOLLAPSE PHASE OF THE PLUME)
      INDEX=ISTEP
      V5=V2
      NC=K*L
      NE=10+NC
C     NE=NO. OF TOTAL EQS
      UOLD=U(ISTEP)*DL(ISTEP)/DS
      DO 101 KK=1,NE
  101 SAVE(KK)=E(KK)
   25 DO 102 KK=1,NE
  102 E(KK)=SAVE(KK)
      IJK=IJK+1
      DS=DINCR*BC(INDEX)
      ISTEP=INDEX
      UUU=UOLD
      V2=V5
      DO 103 KK=4,8
  103 F(KK)=E(KK)*DS
      DO 104 KK=10,NE
  104 E(KK)=F(KK)*DS
      DLDT=0.
      DL(ISTEP)=DS
      IF(METHOD .EQ. 2)105,106
  105 VF=FV*PAI*BC(ISTEP)**2*DS
      GO TO 107
  106 VF=FV*DS/DSS
  107 CONTINUE
      NOTRN=0
```

```
C      NOTRN -INDICATE ENTRAINMENT EITHER BY CONVECTION OR BY COLLAPSE
       NUTRL=0
C      NUTRL -INDICATE DIFFUSION TAKING  OVER
       IPLUNG=0
C      IPLUNG=INDICATOR OF HITTING BOTTOM
       IF(ISTEP .EQ. IBED)IPLUNG=1
       IF(NOTE .EQ. 1) GO TO 500
       IF(ISTEP .EQ. INDEX)GO TO 121
   110 CX(ISTEP)=E(1)
       CY(ISTEP)=E(2)
       CZ(ISTEP)=E(3)
       CMMASS=1./(CM*E(4))
       V1=E(5)*CMMASS
       V3=E(7)*CMMASS
       UU=    SQRT(V1**2+V3**2)
       DL(ISTEP)=UU*DL(ISTEP-1)/UUU
       DLDT=(DL(ISTEP)-DL(ISTEP-1))*UUU/DL(ISTEP-1)
       VOLUME=(E(4)+E(8))/ROA(1)
       ROO=E(4)/ VOLUME
       AREA=VOLUME/DL(ISTEP)
       BC(ISTEP)=E(9)
C      BC=MAJOR RAIUS OF CLOUD
       AA(ISTEP)=AREA/(PAI*E(9))
       V2=E(6)*CMMASS*AA(ISTEP)/BC(ISTEP)
       U(ISTEP)=SQRT(V1**2+V2**2+V3**2)
       THETA2(ISTEP)=.5*PAI
       DS=U(ISTEP)*DL(ISTEP)/UU
       AKX=2.29*ALAMDA*       E(9) **.333333
       BBDT=(BC(ISTEP)-BC(ISTEP-1))*UUU/DL(ISTEP-1)
       IF(ISTEP.LE.INDEX+5) GO TO 111
       IF(AKX .GE. BBDT)NUTRL=3
       IF(CY(ISTEP)-AA(ISTEP).LE.0.) GO TO 220
   111 CONTINUE
       UUU=UU
       UU=1./UU
       SZETA(ISTEP)=V3*UU
       CZETA(ISTEP)=V1*UU
       ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
       DENDIF(ISTEP)=(ROO-ROAA)*.51545
       KK=1
       DO 120 I=1,K
       DO 120 J=1,L
       SS(KK ,ISTEP)=E(10+KK)/VOLUME
   120 KK=KK+1
C      SS SAVE SOLIDS FOR LONG TERM DIFFUSION, CONC. IN  VOL. RATIO
       FC(ISTEP)=VF/VOLUME
       IF(IPLUNG .EQ. 4) GO TO 122
       IF((CY(ISTEP)+AA(ISTEP)*.85)           .GE. H) IPLUNG=2
   122 IF(NUTRL .EQ. 3) GO TO 200
       IF (IPLUNG .EQ. 2) GO TO 300
       IF(ISTEP .GE. 599) GO TO 200
   121 CALL RUNGS(DERIVE4,NE)
       DT= DS/U(ISTEP)
       ISTEP=ISTEP+1
       T(ISTEP)=T(ISTEP-1)+DT
       S(ISTEP)=S(ISTEP-1)+DS
       GO TO 110
   300 CONTINUE
       A0=A0*2.
       DBT=E(10)*3./(AA(ISTEP)*BC(ISTEP)*ROO*DL(ISTEP))
```

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```
      E(10)=ROO*AA(ISTEP)*BC(ISTEP)*(DBT       /AA(ISTEP))/1.5*DL(ISTEP)
     ,  +.375*PAI*BC(ISTEP)*V2
      IBED=ISTEP
  500 CALL BOTTOM2
      IF(ISTEP .GE. 600) GO TO 2020
      IF(NUTRL .EQ. 3) GO TO 200
      IF(IPLUNG .EQ. 4)160,500
  160 E(6)=CM*E(4)*V2
      ROO=E(4)*ROA(1)/(E(4)+E(8))
      DBT=E(10)*1.5/(AA(ISTEP)*BC(ISTEP)*ROO*DL(ISTEP))
      E(10)=ROO*AA(ISTEP)*BC(ISTEP)*DBT/3.*DL(ISTEP)
      A0=A0*.5
      ILEAVE=ISTEP
      NOTRN=1
      GO TO 121
 2020 ISTEP=ISTEP-1
  200 WRITE(6,90056)IJK,DINCR,BC(INDEX),IPLUNG,NUTRL,ISTEP
90056 FORMAT(1X,I5,2F12.4,3I5)
      IF(IJK .EQ. 5) GO TO 220
      IF((ISTEP-INDEX) .LT. 100 .OR. (ISTEP-INDEX) .GT. 400) 210,220
  210 DINCR=DINCR*(ISTEP-INDEX)/240.
      GO TO 25
  220 CONTINUE
      IF(IPCL.EQ.0) GO TO 8001
      WRITE(6,90053)
90053 FORMAT(18X,1HT,7X,1HS,7X,1HX,7X,1HY,7X,1HZ,7X,1HU,7X,1HA,7X,1HB,5X
     ,,7HDEN-DIF,2X,11HFLUID CONC.,13H  SOLID VOL. ,2X,13HCONCENTRATION)
      NGRID=(ISTEP-INDEX)/100
      IF(NGRID .LE. 0) NGRID=1
      DO 240 JJJ=INDEX,ISTEP,NGRID
      DO 230 KK=1,NC
  230 ACONC(KK)=    PAI*BC(JJJ)*AA(JJJ)*SS(KK,JJJ)*DL(JJJ)
      WRITE(6,90054)T(JJJ),S(JJJ),CX(JJJ),CY(JJJ),CZ(JJJ),U(JJJ),
     ,   AA(JJJ),BC(JJJ),DENDIF(JJJ),FC(JJJ),ACONC(1),SS(1,JJJ)
90054 FORMAT(10X,3F9.2,5F8.2,4E12.4)
      IF(NC .EQ. 1) GO TO 240
      DO 201 KK=2,NC
  201 WRITE(6,90055)ACONC(KK),SS(KK,JJJ)
90055 FORMAT(101X,2E12.4)
  240 CONTINUE
 8001 IF(IGCL.EQ.0) GO TO 8002
      ISTEP1=ISTEP+1
      CZ(ISTEP1)=2.*CZ(ISTEP)-CZ(ISTEP-1)
      CX(ISTEP1)=2.*CX(ISTEP)-CX(ISTEP-1)
      AA(ISTEP1)=0.
      CY(ISTEP1)=0.
      BC(ISTEP1)=0.
      CALL DRAW(CX,CX,CX,CX,AA,BC,CZ,CY  ,ISTEP1,4,NSCALE,4)
 8002 CONTINUE
      DO 260 KK=1,NC
      CMAX(KK)=SS(KK,ISTEP)
  260 CONTINUE
      CMAX(NC+1)=FC(ISTEP)
      IF(WS(1,1) .EQ. 0.)CMAX(1)=CMAX(2)
      YY=E(2)
      IF(CY(ISTEP)-AA(ISTEP).LE.0.) YY=AA(ISTEP)
      A0=AA(ISTEP)
      DT2=DS/U(ISTEP)
      RETURN
      END
      SUBROUTINE BOTTOM1
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),COLAPV(600),
     ,CZ(600),SS(8,600),SAVE(600),DUMY2(6,600),FC(600),BC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TCRS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /COMPUT/EE(7,151),E(20),ACONC(123),CS(4,2),
     ,    D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,OLDT,METHOD,TSTOP
      NF=10+K*L
      VOLUME=(E(4)+E(8))/ROA(1)
      BC(ISTEP)=E(9)
      AA(ISTEP)=3.*VOLUME/(4.*PAI*BC(ISTEP)**2)
      ROO=E(4)/VOLUME
      IF(ISTEP .EQ. IBED)124,125
  124 FBED=0.
      GO TO 126
  125 CX(ISTEP)=E(1)
      CY(ISTEP)=E(2)
      CZ(ISTEP)=E(3)
      CMMASS=1./(CM*E(4))
      U(ISTEP)=E(5)*CMMASS
      V(ISTEP)=.75*16.*E(10)/(PAI*BC(ISTEP)**3*ROO)
      W(ISTEP)=E(7)*CMMASS
      FBED=0.
      KK=1
      DO 120 I=1,K
      DO 120 J=1,L
      IF (ABS(V(ISTEP)) .LE. ABS(WS(I,J))) 121,122
  121 BETAA=1.
      GO TO 123
  122 BETAA=BETA
  123 SS(KK,ISTEP)=E(10+KK)/VOLUME
      FBED=FBED-PAI*BC(ISTEP)**2*ABS(WS(I,J))*ROAS(I) *SS(KK,ISTEP)
     ,       *(1.-BETAA)*V(ISTEP)
  120 KK=KK+1
      FC(ISTEP)=VF/VOLUME
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA)*.51545
      FBED=FBED+1.33333*PAI*AA(ISTEP)*BC(ISTEP)**2*(ROO-ROAA)*G
     ,    -CM*(E(4)*V(ISTEP)-E(6)*V(ISTEP-1))/DT
      AKX=2.*ALAMDA*(.5*E(9))**.333333
C     AKX - CHANGE OF B BY DIFFUSION
      BBDT=(BC(ISTEP)-BC(ISTEP-1))/DT
      IF(AKX .GE. BBDT) NUTRL=3
  126 E(6)=E(4)
C     STORE OLD MASS IN E(6)
      IF(FBED .LT. 0.) IPLUNG=4
      IF(NUTRL .EQ. 3) GO TO 200
      IF(IPLUNG .EQ. 4) ILEAVE=ISTEP
      IF(IPLUNG .EQ. 4) GO TO 200
      CALL RUNGS(DERIVE6,NE)
      ISTEP=ISTEP+1
      T(ISTEP)=T(ISTEP-1)+DT
  200 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE BOTTOM2
      EXTERNAL DERIVE1,DERIVE2,DERIVE3,DERIVE4,DERIVE5,DERIVE6,DERIVE7
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON        CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),DENDIF(600),   DL(600),
     ,  CZ(600),SS(8,600),SAVE(600),DUMY2(5,600),FC(600),T(600),
     ,     BC(600),WS(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,              UBX,WBZ,  V2,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DS,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /COMPUT/EE(7,151),E(20),BLANK(125),CS(4,2),
     ,    D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NUTE,A0,IY,NUTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      NE=10+K*L
      IF(ISTEP .EQ. IBED)124,125
  124 FBED=0.
      UUU=U(ISTEP)*DL(ISTEP)/DS
      GO TO 126
  125 CX(ISTEP)=E(1)
      CY(ISTEP)=E(2)
      CZ(ISTEP)=E(3)
      CMMASS=1./(CM*E(4))
      V1=E(5)*CMMASS
      V3=E(7)*CMMASS
      UU=   SQRT(V1**2+V3**2)
      DL(ISTEP)=UU*DL(ISTEP-1)/UUU
      DLDT=(DL(ISTEP)-DL(ISTEP-1))*UUU/DL(ISTEP-1)
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      BC(ISTEP)=E(9)
      V2=E(10)*4./(PAI*BC(ISTEP)**2*ROO *DL(ISTEP))
      U(ISTEP)=SQRT(V1**2+V2**2+V3**2)
      AREA=VOLUME/DL(ISTEP)
      AA(ISTEP)=AREA/(PAI*E(9))
      THETA2(ISTEP)=.5*PAI
      DS=U(ISTEP)*DL(ISTEP)/UU
      UUU=UU
      UU=1./UU
      SZETA(ISTEP)=V3*UU
      CZETA(ISTEP)=V1*UU
      ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      DENDIF(ISTEP)=(ROO-ROAA)*.51545
      FBED=0.
      KK=1
      DO 120 I=1,K
      DO 120 J=1,L
      SS(KK ,ISTEP)=E(10+KK)/VOLUME
      IF(ABS(WS(I,J)) .LE. ABS(V2))121,122
  121 BETAA=1.
      GO TO 123
  122 BETAA=BETA
  123 FBED=FBED-2.*BC(ISTEP)*ABS(WS(I,J))*ROAS(I)*SS(KK,ISTEP)
     ,        *(1.-BETAA)*V4       *DL(ISTEP)
  120 KK=KK+1
```

```
C      SS SAVE SOLIDS FOR LONG TERM DIFFUSION. CONC. IN  VOL. RATIO
       FC(ISTEP)=VF/VOLUME
       FBED=FBED+PAI    *AA(ISTEP)*BC(ISTEP)*(ROO-ROAA)*G*DL(ISTEP)
     ,     -CM*(E(4)*V2       -E(6)*V4          )*UUU/DL(ISTEP-1)
       AKX=2.29*ALAMDA*       E(9) **.333333
       BPDT=(BC(ISTEP)-BC(ISTEP-1))*UUU/DL(ISTEP-1)
       IF(AKX .GE. BPDT)NUTRL=3
   126 E(6)=E(4)
       V4=V2
C      STORE OLD MASS IN E(6)
       IF(FBED .LT. 0.) IPLUNG=4
       IF(NUTRL .EQ. 3) GO TO 200
       IF(IPLUNG .EQ. 4) ILEAVE=ISTEP
       IF(IPLUNG .EQ. 4) GO TO 200
       CALL RUNGS(DERIVE7,NE)
       DT= DS/U(ISTEP)
       ISTEP=ISTEP+1
       T(ISTEP)=T(ISTEP-1)+DT
       S(ISTEP)=S(ISTEP-1)+DS
   200 CONTINUE
       RETURN
       END
VV
```

```
      SUBROUTINE RUNGS(DERIVE,NF)
C
      COMMON /A/ FP(20)
      COMMON /COMPUT/EF(7,151),E(20),W1(20),W2(20),W3(20),W4(20),Z(20),
     ,              BLANK(31),
     ,    D(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,               CCMAX(151),VAR(151)
      COMMON /TORB/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
C
C
      CALL DFRIVE(E)
      DO 2 I=1,NE
      W1(I)=DT*EP(I)
    2 Z(I)=F(I)+ W1(I)*0.5
      CALL DERIVE(Z)
      DO 3 I=1,NE
      W2(I)=DT*EP(I)
    3 Z(I)=F(I)+W2(I)*0.5
      CALL DERIVE(Z)
      DO 4 I=1,NE
      W3(I)=DT*EP(I)
    4 Z(I)=F(I)+W3(I)
      CALL DERIVE(Z)
      DO 7 I=1,NE
      W4(I)=DT*EP(I)
    7 E(I)=F(I)+(2.*(W2(I)+W3(I))+W1(I)+W4(I))/6.
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVE1(E)
C
      DIMENSION E(20)
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),ENTHCO(600),
     ,                CZ(600),SS(8,  600),DUMY2(8,600),BC(600),W8(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CE=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      B=(VOLUME*3./(2.*PAI))**0.333333
      IF (ROO .LE. ROAA) NUTRL=1
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 IF(E(9)) 141,141,142
  141 ALPHA=ALPHA0
      GO TO 143
  142 ALPHA=ALPHA0*SQRT( TANH ((G*VOLUME*(ROO-ROAA)/(2.*PAI*.16*ROO*
     ,                    E(9)**2*ALPHA0))**2))
C     MAIN COMPUTATIONS
  143 CMMASS=CM*E(4)
      UU=E(5)/CMMASS
      VV=E(6)/CMMASS
      WW=E(7)/CMMASS
      PHI=SQRT((UU-UA)**2+VV**2+(WW-WA)**2)
      ENTRV=2.*PAI*B**2*ALPHA*PHI
      DRAG=CD*ROAA    *PAI*B**2*PHI*.5
      EP(1)=UU
      EP(2)=VV
      EP(3)=WW
      EP(4)=ENTRV*ROAA
      EP(5)=ENTRV*ROAA*UA -DRAG*(UU-UA)*.5
      EP(6)=VOLUME *(ROO-ROAA)*G-DRAG*VV
      EP(7)=ENTRV*ROAA*WA-DRAG*(WW-WA)*.5
      EP(8)=ENTRV*(ROA(1)-ROAA)
      EP(9)=-3.*B**2*G*CE/ROA(1)
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(VV))151,151,152
C     IF FALL VEL. IS SMALLER  THAN THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETLV=PAI*B**2*ABS(WS(I,J))*(1.-BETAA)*E(9+KK)/VOLUME
      EP(4)=EP(4)-SETLV*(ROAS(I)     )
      EP(5)=EP(5)-SETLV*(ROAS(I)     )*UU
      EP(6)=EP(6)-SETLV*(ROAS(I)     )*VV
      EP(7)=EP(7)-SETLV*(ROAS(I)     )*WW
      EP(8)=EP(8)-SETLV*(ROA(1)-ROAS(I)     )
      EP(9+KK )=-SETLV
  150 KK=KK+1
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVE2(E)
      DIMENSION E(20)
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,               YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,                CZ(600),SS(8,  600),DUMY2(8,600),RC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FRED,AM0,DLDT,METHOD,TSTOP
C
C
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
      CALL EXIT
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      IF(ROO .GE. ROAA) NOTRN=1
      IF(NOTRN .EQ. 1) 10,20
   10 ALPHA0=0
      ALPHA=ALPHAC
   20 CONTINUE
      CE=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 B=E(9)
      A=3.*VOLUME/(4.*PAI*B**2)
      CMMASS=CM*E(4)
      CMMASSS=CMMASS*B/A
      UU=E(5)/CMMASS
      VV=E(6)/CMMASSS
      WW=E(7)/CMMASS
      PHI=SQRT((UU-UA)**2+VV**2+(WW-WA)**2)
      EP(9)=E(10)*16./(PAI*A*B**2*ROO)
      AREA1=B**2
      DUMY=SQRT(ABS(B**2-A**2))
      IF (DUMY .LT. 0.000001)1,2
    1 AREA2=B**2
```

```
      GO TO 3
    2 AREA2=A**2*B/DUMY
      AREA2=AREA2*ALOG((DUMY+A)/A)
    3 ENTRV=2.*PAI*(AREA1+AREA2)*(PHI*ALPHA0+ALPHA*EP(9))
C     ENTRV=ENTRAINMENT IN VOLUME
C     MAIN COMPUTATIONS
      EP(1)=UU
      EP(2)=VV
      EP(3)=WW
      DRAG=   PAI*ROAA*PHI*.5
      EP(4)=ENTRV*ROAA
      EP(5)=ENTRV*ROAA*UA-DRAG*A*B*(UU-UA)*CD3
      EP(6)=VOLUME*(ROO-ROAA)*G-DRAG*B**2*VV*CD4
      EP(7)=ENTRV*ROAA*WA-DRAG*A*B*(WW-WA)*CD3
      EP(8)=ENTRV*(ROA(1)-ROAA)
      EP(10)=     PAI*(1.-GAMA*A0/A)*CE*G*A**3*B/16.
     ,        -CDRAG*ROAA*A*B*EP(9)* ABS(EP(9))/4.
     ,        -CFRIC*ROAA*B**2*EP(9)/(2.*A)
      DV=ENTRV*ROAA
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(VV))151,151,152
C     IF FALL VEL. IS SMALLER THAN  THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETLV=PAI*B**2*ABS(WS(I,J))*(1.-BETAA)*E(10+KK)/VOLUME
      EP(4)=EP(4)-SETLV*(ROAS(I)     )
      EP(5)=EP(5)-SETLV*(ROAS(I)     )*UU
      EP(6)=EP(6)-SETLV*(ROAS(I)     )*VV
      EP(7)=EP(7)-SETLV*(ROAS(I)     )*WW
      EP(8)=EP(8)-SETLV*(ROA(1)-ROAS(I)     )
      EP(10+KK)=-SETLV
      DV=DV-SETLV*ROAS(I)
  150 KK=KK+1
      EP(9)=EP(9)+DV*0.375/(PAI*A*B*ROO)
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVE3 (E)
      DIMENSION E(20)
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON        CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),DENDIF(600),   DL(600),
     ,              CZ(600),SS(8,  600),DUMY2(8,600),BC(600),W8(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,              UBX,WBZ,  V2,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DS,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CE=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      UU=SQRT(E(5)**2+E(6)**2+E(7)**2)/E(4)
      BB=SQRT((E(4)+E(8))/(ROA(1)*UU*PAI))
      FLUX=PAI*BB**2*UU
      ROO=E(4)/FLUX
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 CONTINUE
      UA=UA-UBX
      WA=WA-WBZ
      DEN1=SQRT(UA**2+WA**2)
      COSD1=UA/DEN1
      COSD3=WA/DEN1
      DENO=E(4)*UU
      DIRCOS1=E(5)/DENO
      DIRCOS2=E(6)/DENO
      DIRCOS3=E(7)/DENO
      COSGAMA=COSD1*DIRCOS1+COSD3*DIRCOS3
      AGAMA= ACOS(COSGAMA)
      FD=CD*ROAA*(UA**2+WA**2)*SIN(AGAMA)**2*BB
      DENO=SIN(AGAMA)
      FDX=(COSD1-COSGAMA*DIRCOS1)*FD/DENO
      FDY=-COSGAMA*DIRCOS2*FD/DENO
      FDZ=(COSD3-COSGAMA*DIRCOS3)*FD/DENO
      IF(ABS(DIRCOS2) .GE. 1.0)DIRCOS2=ABS(DIRCOS2)/DIRCOS2
      TETA2= ACOS(DIRCOS2)
      ENTR=2.*PAI*BB*(ALPHA1*(UU-DEN1*COSGAMA)
     ,    +ALPHA2*ABS(SIN(TETA2)*DENO   )*DEN1)
      EP(1)=DIRCOS1
      EP(2)=DIRCOS2
      EP(3)=DIRCOS3
      EP(4)=ENTR *ROAA
      EP(5)=ENTR *ROAA*UA+FDX
      EP(6)=G*(ROC-ROAA)*PAI*BB**2+FDY
      EP(7)=ENTR *ROAA*WA+FDZ
      EP(8)=ENTR *(ROA(1)-ROAA)
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(UU*DIRCOS2)) 151,151,152
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETL=2.*BB*ABSWS*(1.-BETAA)*E(8+KK)*SIN(TETA2)/FLUX
      EP(4)=EP(4)-SETL *(ROAS(I)     )
      RUU=ROAS(I)*UU
      EP(5)=EP(5)-SETL*RUU*DIRCOS1
      EP(6)=EP(6)-SETL*RUU*DIRCOS2
      EP(7)=EP(7)-SETL*RUU*DIRCOS3
      EP(8)=EP(8)-SETL *(ROA(1)-ROAS(I)     )
      EP(8+KK )=-SETL
  150 KK=KK+1
      RETURN
      END
vv
```

```
      SUBROUTINE DERIVE4(E)
      DIMENSION E(20)
C
C
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON         CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AB  (600),DENDIF(600),   DL(600),
     ,               CZ(600),SS(8,  600),DUMY2(8,600),BC(600),WS(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,               UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT   )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CE=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 CONTINUE
      UA=UA-UBX
      WA=WA-WBZ
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      AREA=VOLUME/DL(ISTEP)
      BB=E(9)
      AA=AREA/(PAI*BB)
      CMMASS=1./(CM*E(4))
      V1=E(5)*CMMASS
      V2=E(6)*CMMASS*AA/BB
      V3=E(7)*CMMASS
      UU=SQRT(V1**2+V2**2+V3**2)
      PHI=SQRT((V1-UA)**2+V2**2+(V3-WA)**2)
      IF(ROO .GE. ROAA) NOTRN=1
      SF=PAI*SQRT(2.*(AA**2+BB**2))
      EP(9)=E(10)*3./(ROO*UU*AA*BB*DL(ISTEP))
      IF(NOTRN .NE. 1) 10,20
```

```
   10 ENTR=ALPHA3*SF*PHI*DL(ISTEP)
      GO TO 30
   20 ENTR=ALPHA4*SF*EP(9)*UU*DL(ISTEP)
   30 CONTINUE
C     ENTR -ENTRAINMENT IN VOLUME
C     MAIN COMPUTATIONS
      UUU=1./SQRT(V1**2+V3**2)
      PX=V3*UUU
      PZ=V1*UUU
      DRAG1=.5*CD3*ROAA*PHI
      DRAG2=.5*CD4*ROAA*PHI
      EP(1)=V1
      EP(2)=V2
      EP(3)=V3
      EP(4)=ENTR *ROAA
      EP(5)=ENTR *ROAA*UA-DRAG1*AA*PX*(V1-UA)*2.*DL(ISTEP)
      EP(6)=G*(ROO-ROAA)*PAI*BB*AA*DL(ISTEP)-DRAG2*BB*V2*2.*DL(ISTEP)
      EP(7)=ENTR *ROAA*WA-DRAG1*AA*PZ*(V3-WA)*2.*DL(ISTEP)
      EP(8)=ENTR *(ROA(1)-ROAA)
      EP(9)=EP(9)-BB*DLDT/DL(ISTEP)
      EP(10)=.1666667  *CE*(1.-GAMA*A0/AA)*AA**3*G*DL(ISTEP)/UU
     ,   -CDRAG*.5*ROAA*AA*UU*EP(9)*ABS(EP(9)) *DL(ISTEP)
     ,    -CFRIC*BB*EP(9)*DL(ISTEP)/AA
      DV=ENTR*ROAA
      UU=1./UU
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(V2          ))151,151,152
C     IF FALL VEL. IS SMALLER THAN  THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETL =2.*BB*ABSWS*DL(ISTEP)*(1.-BETAA)*E(10+KK)/VOLUME
      EP(4)=(EP(4)-SETL*ROAS(I))
      EP(5)=(EP(5)-SETL*ROAS(I)*V1)
      EP(6)=(EP(6)-SETL*ROAS(I)*V2)
      EP(7)=(EP(7)-SETL*ROAS(I)*V3)
      EP(8)=(EP(8)-SETL *(ROA(1)-ROAS(I)))
      EP(10+KK)=-SETL*UU
      DV=DV-SETL*ROAS(I)
  150 KK=KK+1
      EP(9)=EP(9)+DV*UU/(PAI*AA*ROO*DL(ISTEP))
      DO 160 KK=1,8
  160 EP(KK)=EP(KK)*UU
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVES (E)
      DIMENSION E(20)
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON        CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),  AA(600),DENDIF(600),   DL(600),
     ,              CZ(600),SS(8,  600),DUMY2(8,600),HC(600),WS(4,2),
     ,       ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,TJK,FRED,AM0,DLDT,METHOD,TSTOP
C
C
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CF=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 CONTINUE
      UA=UA-UBX
      WA=WA-WBZ
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      AREA=VOLUME/DL(ISTEP)
      IF(ROO .LT. ROAA )NUTRL=1
      BB=SQRT(2.*AREA/PAI)
      CMMASS=1./(CM*E(4))
      V1=E(5)*CMMASS
      V2=E(6)*CMMASS
      V3=E(7)*CMMASS
      UU=SQRT(V1**2+V2**2+V3**2)
      PHI=SQRT((V1-UA)**2+V2**2+(V3-WA)**2)
      RCY=SQRT((V1-UA)**2+       (V3-WA)**2)
      ENTR=PAI*BB*DL(ISTEP)*(ALPHA*V2+RCY*ALPHA1)
C     ENTR =ENTRAINMENT IN VOLUME
      UUU=1./SQRT(V1**2+V3**2)
      PX=V3*UUU
      PZ=V1*UUU
      DRAG1=.5*CD1*ROAA*PHI
      DRAG2=.5*CD2*ROAA*PHI
      EP(1)=V1
      EP(2)=V2
      EP(3)=V3
      EP(4)=ENTR *ROAA
      EP(5)=ENTR *ROAA*UA-DRAG1*BB*PX*(V1-UA)*DL(ISTEP)
      EP(6)=G*(ROO-ROAA)*PAI*BB**2*.5*DL(ISTEP)-DRAG2*BB*V2*2.*DL(ISTEP)
      EP(7)=ENTR *ROAA*WA-DRAG1*BB*PZ*(V3-WA)*DL(ISTEP)
      EP(8)=ENTR *(ROA(1)-ROAA)
      UU=1./UU
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(V2          ))151,151,152
C     IF FALL VEL. IS SMALLER THAN  THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETL =2.*BB*ABSWS*DL(ISTEP)*(1.-BETAA)*F( 8+KK)/VOLUME
      EP(4)=(EP(4)-SETL*ROAS(I))
      EP(5)=(EP(5)-SETL*ROAS(I)*V1)
      EP(6)=(EP(6)-SETL*ROAS(I)*V2)
      EP(7)=(EP(7)-SETL*ROAS(I)*V3)
      EP(8)=(EP(8)-SETL *(ROA(1)-ROAS(I)))
      EP( 8+KK)=-SETL*UU
  150 KK=KK+1
      DO 160 KK=1,8
  160 EP(KK)=EP(KK)*UU
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVE6(E)
      DIMENSION E(20)
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,                CZ(600),SS(8,  600),DUMY2(8,600),BC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRI,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CE=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 CONTINUE
      B=E(9)
      A=3.*VOLUME/(2.*PAI*B**2)
      EP(9)=E(10)*16./(PAI*A*B**2*ROO)
      CMMASS=1./(CM*E(4))
      UU=E(5)*CMMASS
      VV=.75*A*EP(9)/B
      WW=E(7)*CMMASS
      PHI=SQRT((UU-UA)**2+VV**2+(WW-WA)**2)
      PH=SQRT(UU**2+WW**2)
      IF(PH .LE. 0.0001) 201,202
  201 PH=0.
      GO TO 203
  202 PH=1./PH
  203 CONTINUE
      AREA1=B**2
      DUMY=SQRT(ABS(B**2-A**2))
      IF (DUMY .LT. 0.000001)1,2
    1 AREA2=B**2
      GO TO 3
    2 AREA2=A**2*B/DUMY
      AREA2=AREA2*ALOG((DUMY+A)/A)
    3 ENTRV=   PAI*(AREA1+AREA2)*(PHI*ALPHA0+ALPHAC*EP(9))
C     ENTRV=ENTRAINMENT IN VOLUME
C     MAIN COMPUTATIONS
      EP(1)=UU
      EP(2)=VV
      EP(3)=WW
      EP(4)=ENTRV*ROAA
      DRAG=   PAI*ROAA*PHI*.5
      EP(5)=ENTRV*ROAA*UA-DRAG*A*B*(UU-UA)*CD3*.5-FBED*FRICTN*UU*PH
      EP(6)=0.
      EP(7)=ENTRV*ROAA*WA-DRAG*A*B*(WW-WA)*CD3*.5-FBED*FRICTN*WW*PH
      EP(8)=ENTRV*(ROA(1)-ROAA)
      EP(10)=      PAI*(1.-GAMA*A0/A)*CE*G*A**3*B/16.
     ,        -CDRAG*ROAA*A*B*EP(9)* ABS(EP(9))/4.
     ,        -CFRIC*ROAA*B**2*EP(9)/(2.*A)
     ,   -F1* FBED*FRICTN/(2.*PAI)
      DV=ENTRV*ROAA
      KK=1
      DO 150 I=1,K
      DO 150 J=1,L
      ABSWS=ABS(WS(1,J))
      IF(ABSWS-ABS(VV))151,151,152
C     IF FALL VEL. IS SMALLER THAN  THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETLV=PAI*B**2*ABS(WS(I,J))*(1.-BETAA)*F(10+KK)/VOLUME
      EP(4)=EP(4)-SETLV*(ROAS(I)     )
      EP(5)=EP(5)-SETLV*(ROAS(I)     )*UU
      EP(7)=EP(7)-SETLV*(ROAS(I)     )*WW
      EP(8)=EP(8)-SETLV*(ROA(1)-ROAS(I)     )
      EP(10+KK)=-SETLV
      DV=DV-SETLV*ROAS(I)
  150 KK=KK+1
      EP(9)=EP(9)+DV* 0.75/(PAI*A*B*ROO)
      RETURN
      END
VV
```

```
      SUBROUTINE DERIVE7(E)
      DIMENSION E(20)
C
      COMMON /A/ EP(20)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,               YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON          CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AB  (600),DENDIF(600),   DL(600),
     ,                CZ(600),SS(8,  600),DUMY2(8,600),BC(600),WS(4,2),
     ,       ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FRED,AMO,DLDT,METHOD,ISTOP
      IF(E(2).GE.0.) GO TO 888
      WRITE(6,999)
      CALL EXIT
  999 FORMAT(  47H Y LT 0 -- CHANGE INPUT DATA TO ENSURE DESCENT    )
  888 CONTINUE
  100 IF(E(2) .LE. Y(IY+1)) GO TO 101
      IY=IY+1
      GO TO 100
  101 IF(E(2)-Y(IY))102,200,200
  102 IY=IY-1
      GO TO 100
  200 ROAA=ROA(IY)+(E(2)-Y(IY))*(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      CF=(ROA(IY+1)-ROA(IY))/(Y(IY+1)-Y(IY))
      UA=0.
      IF(E(2) .LE. YU) UA=UA0
      IF(E(2) .GT. YU .AND. E(2) .LT. YE) GO TO 110
      GO TO 120
  110 UA= (YE-E(2))*UA0/(YE-YU)
  120 WA=0.
      IF(E(2) .LE. YW) WA=E(2)*WA0/YW
      IF(E(2) .GT. YW .AND. E(2) .LT. YE) GO TO 130
      GO TO 140
  130 WA=(YE-E(2))*WA0/(YE-YW)
  140 CONTINUE
      UA=UA-UBX
      WA=WA-WBZ
      VOLUME=(E(4)+E(8))/ROA(1)
      ROO=E(4)/VOLUME
      AREA=VOLUME/DL(ISTEP)
      BB=E(9)
      AA=2.*AREA/(PAI*BB)
      CMMASS=1./(CM*E(4))
      V1=E(5)*CMMASS
      V2=E(10)*4./(PAI*BB**2*ROO*DL(ISTEP))
      V3=E(7)*CMMASS
      UU=SQRT(V1**2+V2**2+V3**2)
      PHI=SQRT((V1-UA)**2+V2**2+(V3-WA)**2)
      SF=PAI*SQRT(2.*(AA**2+BB**2))
      EP(9)=E(10)*3./(ROO*UU*AA*BB*DL(ISTEP))
      EP(9)=EP(9)-BB*DLDT/DL(ISTEP)
      ENTR=.5*SF*DL(ISTEP)*(          ALPHA4*EP(9)*UU)
C     ENTR =ENTRAINMENT IN VOLUME
C     MAIN COMPUTATIONS
      UUU=1./SQRT(V1**2+V3**2)
      PX=V3*UUU
      PZ=V1*UUU
      DRAG1=.5*CD3*ROAA*PHI
      DRAG2=.5*CD4*ROAA*PHI
      U1=V1+URX
      U3=V3+WRZ
      PH=SQRT(U1**2+U3**2)
      EP(1)=V1
      EP(2)=V2
      EP(3)=V3
      EP(4)=ENTR *ROAA
      EP(5)=ENTR *ROAA*UA-DRAG1*AA*PX*(V1-UA)*2.*DL(ISTEP)
     ,          -FRICTN*FBED*U1*PH
      EP(6)=0.
      EP(7)=ENTR *ROAA*WA-DRAG1*AA*PZ*(V3-WA)*2.*DL(ISTEP)
     ,          -FRICTN*FBED*U3*PH
      EP(8)=ENTR *(ROA(1)-ROAA)
      EP(10)=.1666667  *CF*(1.-GAMA*A0/AA)*AA**3*G*DL(ISTEP)/UU
     ,   -CDRAG*.5*ROAA*AA*UU*EP(9)*ABS(EP(9)) *DL(ISTEP)
     ,    -CFRIC*BB*EP(9)*DL(ISTEP)/AA
     ,      -F1  *FRICTN*FBED
      DV=ENTR*ROAA
      UU=1./UU
      KK=1
      DO 150 I=1,M
      DO 150 J=1,L
      ABSWS=ABS(WS(I,J))
      IF(ABSWS-ABS(V2         ))151,151,152
C     IF FALL VEL. IS SMALLER  THAN THE CONVECTIVE VEL. NO SETTLING OCCURS
  151 BETAA=1.
      GO TO 153
  152 BETAA=BETA
  153 SETL =2.*BB*ABSWS*DL(ISTEP)*(1.-BETAA)*E(10+KK)/VOLUME
      EP(4)=(EP(4)-SETL*ROAS(I))
      EP(5)=(EP(5)-SETL*ROAS(I)*V1)
      EP(7)=(EP(7)-SETL*ROAS(I)*V3)
      EP(8)=(EP(8)-SETL *(ROA(1)-ROAS(I)))
      EP(10+KK)=-SETL*UU
      DV=DV-SETL*ROAS(I)
  150 KK=KK+1
      EP(9)=EP(9)+DV*UU/(PAI*AA*ROO*DL(ISTEP))*2.
      DO 160 KK=1,8
  160 EP(KK)=EP(KK)*UU
      RETURN
      END
VV
```

```
      SUBROUTINE DIFUSN1
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /C/X0,Z0
      COMMON /MATRIX/ A(151),B(151),C(151),CP(151)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON             CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),FNTRCO(600),
     ,              CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UHX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON/CNOMOR/NOMOR,TPLOT
      COMMON/DEBUG/IBUG
      COMMON/KOM2/ IFINISH
      NGRID3=20
C     COMPUTATION STEPS FOR EACH OUTPT IN      LONG TERM DIFFUSION
C     AFTER THE INPUT FROM CONVECTIVE DESCENT AND DYNAMIC COLLAPSE
C     COMPLETED
      TPLOT=T(ISTEP)
      WRITE(6,1)
    1 FORMAT(1H1,///10X,19HLONG TERM DIFFUSION)
      J1=ISIZE
      J2=J1-1
      KK=1
      DO 100 I=1,K
      DO 100 J=1,L
      WW(KK)=WS(I,J)
  100 KK=KK+1
      WW(KK)=0.
C     FALL VELOCITY OF FLUID
      NC=K*L
      DO 5 I=1,NC
    5 ROAS(I)=ROAS(I)/1.94
      NCP1=NC+1
      IF(WW(1) .EQ. 0.) NCP1=1
C     IF THE FIRST FALL VELOCITY IS ZERO ONLY FLUID PART IS THROWN INTO
C     THE LONG TERM DIFFUSION MODEL
      DO 1001 KK=1,NCP1
      IF(KK.EQ.NCP1) ORIGIN=1.33333E-6*PAI*AA(1)*BC(1)**2*DUMY2(1)
      NOTE=0
C     NOTE OF COMPUTING SPREAD0 BEFORE LONG TERM DIFFUSION
      IJK=0
      X0=0.
      Z0=0.
      DO 110 I=1,6
      F(I)=0.
      DO 110 J=1,J1
  110 E(I,J)=0.
C       SET VALUES IN E AND F TO 0.
        IF(KK .EQ. NCP1) GO TO 250
        DO 120 I=1,J2
        DY(I)=H/J2
  120 CONTINUE
        Y1(1)=0.
        Y2(1)=0.
        DO 130 I=2,J1
        Y1(I)=Y1(I-1)+DY(I-1)
        Y2(I)=Y2(I-1)+DY(I-1)
  130 CONTINUE
C       SET UP A GRID OF EQUAL SIZE
        CALL INABCD
        CALL SUMABCD
        WINV=1./WW(KK)
        DO 131 JJ=1,ISTEP
  131 SVOL(JJ)=1.333333*PI*AA(JJ)*RC(JJ)**2*SS(KK,JJ)
        ORIGIN=.000001*SVOL(1)
        DO 132 JJ=2,ISTEP
        II=ISTEP-JJ+2
  132 SVOL(II)=SVOL(II-1)-SVOL(II)
        DO 133 JJ=2,ISTEP
        IF(SVOL(JJ) .GT. ORIGIN) GO TO 134
  133 CONTINUE
        JJ=ISTEP
  134 IBEGIN=JJ
        TT=T(JJ)
        T2GRID=   H/(J2*ABS(WW(KK)))
        DTO=T2GRID
        TPLOT=T(ISTEP)
        IF(TPLOT/T2GRID.GT.100.) T2GRID=0.01*TPLOT
        NCAKE=(TPLOT-TT)/T2GRID
        IF(IPLT.EQ.0) GO TO 12347
        NOUTPT=NCAKE/IPLT
        IF(NOUTPT.LT.1) NOUTPT=1
        GO TO 12348
12347 NOUTPT=5
12348 CONTINUE
        ISTART=JJ
        IF(ISTART .EQ. ISTEP) GO TO 195
  139 IJK=IJK+1
        IF(T2GRID .GE. (T(ISTEP )-T(ISTART  )))135,136
  135 ISTOP=ISTEP
        GO TO 140
  136 IF(ISTART .GE. INDEX) GO TO 137
        NGRID=T2GRID/DT1
        GO TO 138
  137 NGRID=T2GRID/DT2
  138 IF(NGRID .LT. 1) NGRID=1
        ISTOP=ISTART+NGRID
  140 CONTINUE
        IF(IJK .EQ. 1)GO TO 191
        DT=T(ISTOP)-T(ISTART-1)
        NN=IBUG*DT/DTO
        IF(NN .LE. 0) NN=1
        DT=DT/NN
        CALL MATXCO
        OLDTOT=AMO+F(1)
        DO 194 II=1,NN
```

```
 194 CALL SOLUTN
     ZAMO=0.
     DO 997 I=1,J2
 997 ZAMO=ZAMO+(E(1,I)+E(1,I+1))*DY(I)*0.5
     ZEWTOT=ZAMO+F(1)
     IF(ZEWTOT.LE.0.) GO TO 991
     RTOT=OLDTOT/ZEWTOT
     DO 996 I=1,J1
 996 E(1,I)=E(1,I)*RTOT
     F(1)=F(1)*RTOT
 991 CONTINUE
 191 TT=T(ISTOP)
     DO 190 JJ=ISTART,ISTOP
     IF(SVOL(JJ) .GT. ORIGIN)GO TO 142
     SVOL(JJ)=0.
     GO TO 190
 142 IF(WW(KK)) 170,170,143
C    UPDATING FOR SOLID WITH POSTTIVE FALL VELOCITY
 143 IF(JJ .LE. INDEX) 144,145
C    IN THE CONVECTIVE PHASE
 144 THICK(JJ)=CY(JJ-1)                 +WW(KK)*(T(JJ)-T(JJ-1))
    ,      -CY(JJ)
     POSITN(JJ)=CY(JJ)+.625*BC(JJ)+.5*THICK(JJ)
     GO TO 146
 145 IF(JJ .GT. IBED  .AND. JJ .LE. ILEAVE) 151,158
C    IN THE DYNAMIC COLLAPSE PHASE
 158 THICK(JJ)=CY(JJ-1)+AA(JJ-1)+WW(KK)*(T(JJ)-T(JJ-1))-CY(JJ)-AA(JJ)
     POSITN(JJ)=CY(JJ)+AA(JJ)+.5*THICK(JJ)
 146 DIST=H-POSITN(JJ)
     IF(DIST+.5*THICK(JJ) .LE. 0.)GO TO 151
     IF(DIST .GT. .5*THICK(JJ)) GO TO 400
     ENTBED=   .5*THICK(JJ)-DIST
     RATIO=    ENTBED/THICK(JJ)
     RASVOL=RATIO*SVOL(JJ)
     F(1)=F(1)+RASVOL
     F(2)=F(2)+RASVOL  *CX(JJ)
     F(3)=F(3)+RASVOL  *CZ(JJ)
     F(4)=F(4)+RASVOL  *(CX(JJ)**2+.25*BC(JJ)**2)
     F(5)=F(5)+RASVOL  *(CZ(JJ)**2+.25*BC(JJ)**2)
     F(6)=F(6)+RASVOL  *CX(JJ)*CZ(JJ)
     SVOL(JJ)=(1.-RATIO)*SVOL(JJ)
     THICK(JJ)=(1.-RATIO)*THICK(JJ)
     POSITN(JJ)=H-.501*THICK(JJ)
     DIST=.501*THICK(JJ)
 400 IF(JJ .EQ. ISTOP) 401,402
 401 XC(JJ)=CX(JJ)
     ZC(JJ)=CZ(JJ)
     CB(JJ)=BC(JJ)
     SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
     GO TO 190
 402 CONTINUE
     DO 147 J=1,J1
     IF(Y2(J) .GE. POSITN(JJ)) 148,147
 147 CONTINUE
 148 RATIO =(POSITN(JJ)-Y2(J-1))/DY(J-1)
     SUMKY1=SCKY(J-1)+(SCKY(J)-SCKY(J-1))*RATIO
     SUMUA1=SUA(J-1)+(SUA(J)-SUA(J-1))*RATIO
     SUMWA1=SWA(J-1)+(SWA(J)-SWA(J-1))*RATIO
     IF(WW(KK)*(T(ISTOP)-T(JJ)) .GE. DIST) 152,153
 152 THICK(JJ)=SQRT(THICK(JJ)**2+24.*(SCKY(J1)-SUMKY1)*WINV)
```

```
      XC(JJ)=CX(JJ)+(SUA(J1)-SUMUA1)*WINV
      ZC(JJ)=CZ(JJ)+(SWA(J1)-SUMWA1)*WINV
      CB(JJ)=(BC(JJ)**,66666+1,06*ALAMDA*DIST*WINV)**1,5
      IF(WW(KK)*(T(ISTOP)-T(JJ)) .GE, DIST+,5*THICK(JJ)) 149,154
C     THE CLOUD HITS BOTTOM
  151 XC(JJ)=CX(JJ)
      ZC(JJ)=CZ(JJ)
      CB(JJ)=BC(JJ)
  149 F(1)=F(1)+SVOL(JJ)
      F(2)=F(2)+SVOL(JJ)*XC(JJ)
      F(3)=F(3)+SVOL(JJ)*ZC(JJ)
      F(4)=F(4)+SVOL(JJ)*(XC(JJ)**2+,25*CB(JJ)**2)
      F(5)=F(5)+SVOL(JJ)*(ZC(JJ)**2+,25*CB(JJ)**2)
      F(6)=F(6)+SVOL(JJ)*XC(JJ)*ZC(JJ)
      SVOL(JJ)=0,
C     THOSE REACHED   THE BED ARE DEPOSITED THERE
      GO TO 190
  154 ENTBED=WW(KK)*(T(ISTOP)-T(JJ))-DIST+,5*THICK(JJ)
      RATIO=ENTBED/THICK(JJ)
      RASVOL =RATIO*SVOL(JJ)
      F(1)=F(1)+RASVOL
      F(2)=F(2)+RASVOL  *XC(JJ)
      F(3)=F(3)+RASVOL  *ZC(JJ)
      F(4)=F(4)+RASVOL  *(XC(JJ)**2+,25*CB(JJ)**2)
      F(5)=F(5)+RASVOL  *(ZC(JJ)**2+,25*CB(JJ)**2)
      F(6)=F(6)+RASVOL  *XC(JJ)*ZC(JJ)
      SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
      THICK(JJ)=(1,-RATIO)*THICK(JJ)
      POSITN(JJ)=H-,501*THICK(JJ)
C     SAVE THOSE NOT REACHED BOTTOM FOR LONG TERM DIFFUSION
      GO TO 190
  153 POSITN(JJ)=POSITN(JJ)+WW(KK)*(T(ISTOP)-T(JJ))
      DO 155 K=J,J1
      IF(Y2(K) .GE, POSITN(JJ)) 156,155
  155 CONTINUE
  156 RATIO=(POSITN(JJ)-Y2(K-1))/DY(K-1)
      SUMKY2=SCKY(K-1)+(SCKY(K)-SCKY(K-1))*RATIO
      SUMUA2=SUA(K-1)+(SUA(K)-SUA(K-1))*RATIO
      SUMWA2=SWA(K-1)+(SWA(K)-SWA(K-1))*RATIO
      THICK(JJ)=SQRT(THICK(JJ)**2+24,*(SUMKY2-SUMKY1)*WINV)
      XC(JJ)=CX(JJ)+(SUMUA2-SUMUA1)*WINV
      ZC(JJ)=CZ(JJ)+(SUMWA2-SUMWA1)*WINV
      CB(JJ)=(BC(JJ)**,666666+1,06*ALAMDA *(T(ISTOP)-T(JJ)))**1,5
      IF(WW(KK)*(T(ISTOP)-T(JJ)) .GE, DIST-,5*THICK(JJ)) 154,157
  157 SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
      GO TO 190
C     UPDATING FOR SOLID WITH NEGATIVE FALL VELOCITY
  170 IF(JJ .LE, INDEX) 174,175
  174 THICK(JJ)=CY(JJ)-,375*BC(JJ)-(CY(JJ-1)-,375*BC(JJ-1)
     ,     +WW(KK)*(T(JJ)-T(JJ-1)))
      POSITN(JJ)=CY(JJ)-,375*BC(JJ)-,5*THICK(JJ)
      GO TO 176
  175 IF(JJ .GT, IBED  .AND, JJ .LE, ILEAVE) 159,160
C     THE CLOUD HITS BOTTOM
  159 THICK(JJ)=CY(JJ)-1,25*AA(JJ)-(CY(JJ-1)-1,25*AA(JJ-1)
     ,    +WW(KK)*(T(JJ)-T(JJ-1)))
      POSITN(JJ)=CY(JJ)-1,25*AA(JJ)-,5*THICK(JJ)
      GO TO 176
  160 THICK(JJ)=CY(JJ)-AA(JJ)-(CY(JJ-1)-AA(JJ-1)+WW(KK)*(T(JJ)-T(JJ-1)))
      POSITN(JJ)=CY(JJ)-AA(JJ)-,5*THICK(JJ)
```

```
176 DIST=POSITN(JJ)
    IF(DIST+.5*THICK(JJ) .LE. 0.) GO TO 171
    IF(DIST .GT. .5*THICK(JJ)) GO TO 410
    ENTSURF=  .5*THICK(JJ)-DIST
    RATIO=ENTSURF     /THICK(JJ)
    RASVOL=RATIO*SVOL(JJ)
    F(1)=F(1)+RASVOL
    F(2)=F(2)+RASVOL  *CX(JJ)
    F(3)=F(3)+RASVOL  *CZ(JJ)
    F(4)=F(4)+RASVOL  *(CX(JJ)**2+.25*BC(JJ)**2)
    F(5)=F(5)+RASVOL  *(CZ(JJ)**2+.25*BC(JJ)**2)
    F(6)=F(6)+RASVOL  *CX(JJ)*CZ(JJ)
    SVOL(JJ)=(1.-RATIO)*SVOL(JJ)
    THICK(JJ)=(1.-RATIO)*THICK(JJ)
    POSITN(JJ)=  .501*THICK(JJ)
    DIST=.501*THICK(JJ)
410 IF(JJ .EQ. ISTOP) 411,412
411 XC(JJ)=CX(JJ)
    ZC(JJ)=CZ(JJ)
    CB(JJ)=BC(JJ)
    SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
    GO TO 190
412 CONTINUE
    DO 177 J=1,J1
    IF(Y2(J) .GE. POSITN(JJ)) 178,177
177 CONTINUE
178 RATIO =(POSITN(JJ)-Y2(J-1))/DY(J-1)
    SUMKY1=SCKY(J-1)+(SCKY(J)-SCKY(J-1))*RATIO
    SUMUA1=SUA(J-1)+(SUA(J)-SUA(J-1))*RATIO
    SUMWA1=SWA(J-1)+(SWA(J)-SWA(J-1))*RATIO
    IF(-WW(KK)*(T(ISTOP)-T(JJ)) .GE. DIST) 182,183
182 THICK(JJ)=SQRT(THICK(JJ)**2-24.*SUMKY1*WINV)
    XC(JJ)=CX(JJ)-           SUMUA1 *WINV
    ZC(JJ)=CZ(JJ)-           SUMWA1 *WINV
    CB(JJ)=(BC(JJ)**.666666-1.06*ALAMDA*DIST*WINV)**1.5
    IF(-WW(KK)*(T(ISTOP)-T(JJ)) .GE. DIST+.5*THICK(JJ)) 179,184
171 XC(JJ)=CX(JJ)
    ZC(JJ)=CZ(JJ)
    CB(JJ)=BC(JJ)
179 CONTINUE
    F (1)=F(1)+SVOL(JJ)
    F (2)=F(2)+SVOL(JJ)*XC(JJ)
    F (3)=F(3)+SVOL(JJ)*ZC(JJ)
    F (4)=F(4)+SVOL(JJ)*(XC(JJ)**2+.25*CB(JJ)**2)
    F (5)=F(5)+SVOL(JJ)*(ZC(JJ)**2+.25*CB(JJ)**2)
    F (6)=F(6)+SVOL(JJ)*XC(JJ)*ZC(JJ)
    SVOL(JJ)=0.
C   THOSE REACHED   THE SURFACE ARE CONSIDERED TO STAY THERE
    GO TO 190
184 ENTSURF=-WW(KK)*(T(ISTOP)-T(JJ))-DIST+.5*THICK(JJ)
    RATIO =ENTSURF/THICK(JJ)
    RASVOL =RATIO*SVOL(JJ)
    F (1)=F(1)+RASVOL
    F (2)=F(2)+RASVOL  *XC(JJ)
    F (3)=F(3)+RASVOL  *ZC(JJ)
    F (4)=F(4)+RASVOL  *(XC(JJ)**2+.25*CB(JJ)**2)
    F (5)=F(5)+RASVOL  *(ZC(JJ)**2+.25*CB(JJ)**2)
    F (6)=F(6)+RASVOL  *XC(JJ)*ZC(JJ)
C   THOSE REACHED    THE SURFACE IS CONSIDERED TO STAY THERE
    SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
```

```
      THICK(JJ)=(1.-RATIO)*THICK(JJ)
      POSITN(JJ)=.501*THICK(JJ)
C     SAVE THOSE NOT REACHED SURFACE FOR LONG TERM DIFFUSION
      GO TO 190
  183 POSITN(JJ)=POSITN(JJ)+WW(KK)*(T(ISTOP)-T(JJ))
      DO 185 K=1,J
      IF(Y2(K) .GE. POSITN(JJ)) 186,185
  185 CONTINUE
  186 RATIO=(POSITN(JJ)-Y2(K-1))/DY(K-1)
      SUMKY2=SCKY(K-1)+(SCKY(K)-SCKY(K-1))*RATIO
      SUMUA2=SUA(K-1)+(SUA(K)-SUA(K-1))*RATIO
      SUMWA2=SWA(K-1)+(SWA(K)-SWA(K-1))*RATIO
      THICK(JJ)=SQRT(THICK(JJ)**2+24.*(SUMKY2-SUMKY1)*WINV)
      XC(JJ)=CX(JJ)+(SUMUA2-SUMUA1)*WINV
      ZC(JJ)=CZ(JJ)+(SUMWA2-SUMWA1)*WINV
      CB(JJ)=(BC(JJ)**.666666-1.06*ALAMDA*(T(ISTOP)-T(JJ)))**1.5
      IF(-WW(KK)*(T(ISTOP)-T(JJ)) .GE. DIST-.5*THICK(JJ)) 184,187
  187 SVOL(JJ)=SVOL(JJ)/(PAI*CB(JJ)**2*THICK(JJ))
      GO TO 190
  190 CONTINUE
      DO 192 JJ=ISTART,ISTOP
      IF(SVOL(JJ) .LE. 0.) GO TO 192
      CALL INDATA1
  192 CONTINUE
      IF(ISTOP.EQ.ISTEP) GO TO 12346
      KJI=IJK/NOUTPT
      XIJK=IJK
      XXX=XIJK/NOUTPT
      IF(ABS(XXX-KJI).LT.1.E-10)  12346,12345
12346 CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
12345 CONTINUE
      CALL SHIFT
      CALL GRIDSA
      CALL INABCD
      CALL SUMABCD
      CALL INSOL
      IF(ISTOP .EQ. ISTEP) 195,196
  196 ISTART=ISTOP+1
      GO TO 139
  195 CONTINUE
      CDT=DTO/IBUG
  250 NGRID=NGRID3
      IF(WW(KK)) 257,258 ,257
  257 CALL CONVRT2
      CALL ADD
      GO TO 259
  258 IF(KEY3 .EQ. 1) GO TO 1001
      CALL CONVRT2
      DO 256 J=1,J1
      Y1(J)=Y2(J)
      DO 256 I=1,6
  256 E(I,J)=EE(I,J)
  259 TT=T(ISTEP)
      CALL OUTPT
      CALL INABCD
      WRITE(6,2) TT
    2 FORMAT(1H1,10X,42H**INPUT TO LONG TERM DIFFUSION COMPLETED** ,/,10
     *X,4HTIME,G12.5,/,1H1)
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
      ORIGIN=ORIGIN*50000.
      NOTE=0
  255 CALL GRIDSH
      CALL INABCD
      CALL MATXCO
      CALL INSOL
      CALL SHIFT
      OLDTOT=AMO+F(1)
      DO 300 IJ=1,NGRID
      CALL SOLUTN
      TT=TT+DT
  300 CONTINUE
      ZAMO=0.
      DO 999 I=1,J2
  999 ZAMO=ZAMO+(E(1,I)+E(1,I+1))*DY(I)*0.5
      ZEWTOT=ZAMO+F(1)
      IF(ZEWTOT.LE.0.) GO TO 992
      RTOT=OLDTOT/ZEWTOT
      DO 998 I=1,J1
  998 E(1,I)=E(1,I)*RTOT
      F(1)=F(1)*RTOT
  992 CONTINUE
      CALL OUTPT
      IF(NOMOR.EQ.1) GO TO 1000
      IF(TT .GE. TSTOP) GO TO 1000
      IF (WW(KK))310,320 ,310
  310 IF(AMO.LT.ORIGIN) GO TO 1000
      GO TO 255
  320 VMAX=0.
      VMIN=1000000.
      DO 340 I=1,J1
      IF(E(1,I) .LE. 1.000E-15) GO TO 340
      CONC=E(1,I)/VAR(I)
      IF (VMAX .LT. CONC) VMAX=CONC
      IF( VMIN .GT. CONC) VMIN=CONC
  340 CONTINUE
      RATIO=VMIN/VMAX
      IF(RATIO .GE. 0.95) GO TO 1000
      GO TO 255
 1000  CONTINUE
      IFINISH=1
      CALL OUTPT
      DO 1003 I=1,ISTEP
      CX(I)=CX(I)+X0
 1003 CZ(I)=CZ(I)+Z0
 1001 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE DIFUSN2
      COMMON/SHCAKE/AVEDT4
      COMMON /B/DINCR1,DINCR2,KEY1,KEY2,KEY3
      COMMON /C/X0,Z0
      COMMON /MATRIX/ A(151),B(151),C(151),CP(151)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,               YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/FF(8,151),
     ,    F(8,151),Y1(151),Y2(151),DY(150),H(8),FW(8),WW(9),
     ,                CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,AMCVTS
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON            CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),   DIT(600),   DL(600),
     ,                CZ(600),SS(8,  600),
     ,      SVOL(600),XC(600),ZC(600),POSITN(600), T(600),THICK(600),
     ,     SUA(200),SWA(200),SCKY(200),CONC (600),
     ,     BC(600),WS(4,2),
     ,         ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,OLDT,METHOD,TSTOP
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      COMMON/KOH2/ IFINISH
      COMMON/CNOMOR/NOMOR,TPLOT
      COMMON/DEBUG/IBUG
      NGRID3=20
C     COMPUTATION STEPS FOR EACH OUTPT IN     LONG TERM DIFFUSION
      WRITE(6,1)
    1 FORMAT(1H1,///10X,19HLONG TERM DIFFUSION)
      J1=ISIZE
      J2=J1-1
      ISTEPN1=ISTEP-1
      INDEXN1=INDEX-1
      INDEXN2=INDEX-2
      KK=1
      DO 100 I=1,K
      DO 100 J=1,L
      WW(KK)=WS(I,J)
  100 KK=KK+1
      WW(KK)=0.
C     FALL VELOCITY OF FLUID
      NC=K*L
      DO 5 I=1,NC
    5 ROAS(I)=ROAS(I)/1.94
      NCP1=NC+1
      IF(WW(1) .EQ. 0.) NCP1=1
C     IF THE FIRST FALL VELOCITY IS ZERO ONLY FLUID PART IS THROWN INTO
C     THE LONG TERM DIFFUSION MODEL
      T(1)=0.
      DO 498 JJ=2,ISTEP
      T(JJ)=T(JJ-1)+(S(JJ)-S(JJ-1))/U(JJ-1)
  498 CONTINUE
      DO 499 JJ=1,ISTEPN1
      T(JJ)=.5*(T(JJ)+T(JJ+1))
      CX(JJ)=.5*(CX(JJ)+CX(JJ+1))
      CY(JJ)=.5*(CY(JJ)+CY(JJ+1))
      CZ(JJ)=.5*(CZ(JJ)+CZ(JJ+1))
  499 CONTINUE
      T(ISTEP)=T(ISTEP)+.5*DL(ISTEP)/U(ISTEP)
      CX(ISTEP)=CX(ISTEP)+.5*(CX(ISTEP)-CX(ISTEP-1))
      CZ(ISTEP)=CZ(ISTEP)+.5*(CZ(ISTEP)-CZ(ISTEP-1))
      DO 497 JJ=1,ISTEPN1
  497 DTT(JJ)=T(JJ+1)-T(JJ)
      TPLOT=T(ISTEP)+TIME
      T2=T(ISTEP)
      T4=T2+TIME
      DO 1001 KK=1,NCP1
      X0=0.
      Z0=0.
      NOTE=0
      DO 110 I=1,6
      F(I)=0.
      DO 110 J=1,J1
  110 E(I,J)=0.
C     SET VALUES IN E AND F TO 0.
      DO 120 I=1,J2
      DY(I)=H/J2
  120 CONTINUE
      Y1(1)=0.
      Y2(1)=0.
      DO 130 I=2,J1
      Y1(I)=Y1(I-1)+DY(I-1)
      Y2(I)=Y2(I-1)+DY(I-1)
  130 CONTINUE
C     SET UP A GRID OF EQUAL SIZE
      ORIGIN=   PAI*BC(1)**2*U(1)          *5.E-7
      IF(METHOD .EQ. 2)ORIGIN=2.*ORIGIN
      DTO=50.
      IF(KK .EQ. NCP1) 131,132
  131 IF(KEY3 .EQ. 1) 1001,250
  132 TJK=0
      TGRID=   H/(J2*ABS(WW(KK)))
      DTO=TGRID
      ORIGIN=.5*PAI*BC(1)**2*U(1)*SS(KK,1)*.000001
      IF(METHOD .EQ. 2)ORIGIN=2.*ORIGIN
      IF(METHOD .EQ. 3) 401,400
  400 DO 410 JJ=1,INDEX
      SVOL(JJ)=PAI*U(JJ)*BC(JJ)**2*SS(KK,JJ)
  410 CONTINUE
      DO 411 JJ=1,INDEXN1
      SVOL(JJ)=SVOL(JJ)-SVOL(JJ+1)
      IF(SVOL(JJ) .LE. ORIGIN) SVOL(JJ)=0.
  411 CONTINUE
      GO TO 402
  401 DO 403 JJ=1,INDEXN1
      SVOL(JJ)=PAI*AA(JJ)*BC(JJ)*DL(JJ)*SS(KK,JJ)
  403 CONTINUE
      DO 404 JJ=1,INDEXN2
  404 SVOL(JJ)=SVOL(JJ)-SVOL(JJ+1)
      DLINDEX=DL(INDEX-1)*U(INDEX)/U(INDEX-1)
      SLINDEX=PAI*AA(INDEX)*BC(INDEX)*DLINDEX*SS(KK,INDEX)
      SVOL(INDEXN1)=         SVOL(INDEXN1) -SLINDEX
      DO 405 JJ=1,INDEXN1
      SVOL(JJ)=SVOL(JJ)/DTT(JJ)
      IF(SVOL(JJ) .LE. ORIGIN)SVOL(JJ)=0.
  405 CONTINUE
  402 CONTINUE
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      IF(INDEX.EQ.ISTEP) GO TO 414
      DO 412 JJ=INDEX,ISTEP
      SVOL(JJ)=PAI*AA(JJ)*BC(JJ)*DL(JJ)*SS(KK,JJ)
  412 CONTINUE
      DO 413 JJ=INDEX,ISTEPN1
      SVOL(JJ)=(SVOL(JJ)-SVOL(JJ+1))/DTT(JJ)
      IF(SVOL(JJ) .LE. ORIGIN)SVOL(JJ)=0.
  413 CONTINUE
  414 CONTINUE
      SVOL(ISTEP)=0.
      DO 420 JJ=1,ISTEP
      IF(SVOL(JJ) .GT. 0.) 421,420
  420 CONTINUE
      JJ=ISTEP
  421 IBEGIN=JJ
      TT=T(JJ)
      ISTART=JJ
      T1=T(JJ)
      T2=T(ISTEP)
      T3=TIME+T1
      T4=TIME+T2
      TPLOT=T4
      IF(JJ .EQ. ISTEP) GO TO 250
      IF(TPLOT/TGRID.GT.100.) TGRID=TPLOT*.01
      TSTART=T(JJ)
      NCAKE=(T2-TSTART+TIME)/TGRID
      IF(IPLT.EQ.0) GO TO 12347
      NOUTPT=NCAKE/IPLT
      GO TO 12348
12347 NOUTPT=5
12348 CONTINUE
      IF (NOUTPT .LE. 0)NOUTPT=1
      TEND=TSTART+TGRID
  600 CONTINUE
      IJK=IJK+1
      IF(TEND .GT. T2) 422,423
  422 IEND=ISTEP
      IF(TEND .LT. T3) GO TO 426
      DO 428 JJ=ISTART,ISTEP
      IF(TEND .LE. TIME+T(JJ))429,428
  428 CONTINUE
  429 TEND=TIME+T(JJ)
      GO TO 426
  423 DO 424 JJ=IBEGIN,ISTEP
      IF (TEND .LE. T(JJ))425,424
  424 CONTINUE
  425 TEND=T(JJ)
      IEND=JJ
  426 CONTINUE
C     ----------------------------------------------
      DT=TEND-TSTART
      NN=IBUG*DT/DT0
      IF(NN .LE. 0)NN=1
      DT=DT/NN
      IF(IJK .EQ. 1)GO TO 473
      CALL MATXCO
  473 DO 470 II=1,NN
      QAMO=0.
      DO 9871 I=1,J2
 9871 QAMO=QAMO+(F(1,I)+F(1,I+1))*DY(I)*.5
```

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      DTOT=DAMO+F(1)
      IF(IJK .EQ. 1) 471,472
  472 CALL SOLUTN
      ZAMO=0.
      DO 9872 I=1,J2
 9872 ZAMO=ZAMO+(E(1,I)+E(1,I+1))*DY(I)*.5
      ZTOT=ZAMO+F(1)
      IF(ZTOT .LE. 0.)GO TO 9873
      RTOT=DTOT/ZTOT
      DO 9874 I=1,J1
 9874 E(1,I)=F(1,I)*RTOT
      F(1)=F(1)*RTOT
 9873 CONTINUE
  471 CONTINUE
      IF(IEND .EQ. ISTEP) 711,470
  711 IF(TSTART .GE. T2)713,714
  713 AMCVT3=DT/DT2
      GO TO 719
  714 IF(TSTART +II*DT .GT. T2)715,470
  715 IF((TSTART+II*DT-T2)/DT .GT. 1.)713,717
  717 AMCVT3=(TSTART+II*DT-T2)/DT2
  719 CALL CONVRT3
      IF(IJK .EQ. 1)720,721
  720 DO 722 I=1,J1
  722 Y1(I)=Y2(I)
      CALL INABCD
      CALL MATXCD
      DO 723 I=1,6
      DO 723 J=1,J1
  723 E(I,J)=FE(I,J)
      IJK=IJK+1
      GO TO 470
  721 CALL ADD
  470 CONTINUE
      SAVDT4=0.
      DO 430 JJ=ISTART,IEND
      IF(TSTART .GT. T(JJ))431,434
  431 IF(TEND .GT.T3)432,433
  432 IF(TIME+T(JJ) .GT. TEND)433,437
  437 DT3= TIME+T(JJ)-TSTART
      DT4=TEND-TSTART
      GO TO 436
  433 DT3=TEND-TSTART
      DT4=DT3
      GO TO 436
  434 IF(TEND .GT. T3) 439,435
  439 IF(TIME+T(JJ) .GT. TEND)435 ,438
  438 DT3=TIME
      DT4=TEND-T(JJ)
      GO TO 436
  435 DT3=TEND-T(JJ)
      DT4=DT3
  436 CONTINUE
      SAVDT4=SAVDT4+DT4
C     ------------------------------------------------
      THICK(JJ)=ABS(WW(KK))*DT3
      IF(THICK(JJ) .LE. 0.)200,201
  200 CONC(JJ)=0.
      GO TO 430
  201 CONTINUE
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      IF(WW(KK) .LT. 0.) GO TO 500
      CONC(JJ)=SVOL(JJ)*DT3
      IF(METHOD .EQ. 3) GO TO 445
      IF(JJ .LT. INDEX)441,445
  441 POSITN(JJ)=CY(JJ)+SIN(THETA2(JJ))*BC(JJ)+WW(KK)*DT4-.5*THICK(JJ)
      GO TO 449
  445 IF(JJ .LT. INDEX) 446,447
  446 POSITN(JJ)=CY(JJ)+.625*BC(JJ)+WW(KK)*DT4-.5*THICK(JJ)
      GO TO 449
  447 IF(JJ .GT. IBED .AND. JJ .LE. ILEAVE) 450,448
  448 POSITN(JJ)=CY(JJ)+AA(JJ)+WW(KK)*DT4-.5*THICK(JJ)
  449 CONTINUE
      DIST=H-POSITN(JJ)
      IF(DIST+.5*THICK(JJ) .LE. 0.) GO TO 450
      IF(DIST .GE. .5*THICK(JJ)) GO TO 460
      ENTBED=.5*THICK(JJ)-DIST
      RATIO=ENTBED/THICK(JJ)
      RASVOL=RATIO*CONC(JJ)
      CXXJJJ=CX(JJ)-(DT4-0.5*DT3*RATIO)*UBX
      CZZJJJ=CZ(JJ)-(DT4-0.5*DT3*RATIO)*WBZ
      F(1)=F(1)+RASVOL
      F(2)=F(2)+RASVOL*CXXJJJ
      F(3)=F(3)+RASVOL*CZZJJJ
      F(4)=F(4)+RASVOL*(CXXJJJ**2+(DL(JJ)*CZETA(JJ))**2*.083333
     ,     +(BC(JJ)*SZETA(JJ))**2*.333333)
      F(5)=F(5)+RASVOL*(CZZJJJ**2+(DL(JJ)*SZETA(JJ))**2*.083333
     ,      +(BC(JJ)*CZETA(JJ))**2*.333333)
      F(6)=F(6)+RASVOL*(CXXJJJ*CZZJJJ+SZETA(JJ)*CZETA(JJ)*
     ,      (DL(JJ)**2*.083333-BC(JJ)**2*.333333))
      CONC(JJ)=(1.-RATIO)*CONC(JJ)
      THICK(JJ)=(1.-RATIO)*THICK(JJ)
      POSITN(JJ)=H-.501*THICK(JJ)
      CONC(JJ)=CONC(JJ)/(2.*BC(JJ)*DL(JJ)*THICK(JJ))
      GO TO 430
  450 RASVOL=CONC(JJ)
      CXXJJJ=CX(JJ)-(DT4-0.5*DT3)*UBX
      CZZJJJ=CZ(JJ)-(DT4-0.5*DT3)*WBZ
      F(1)=F(1)+RASVOL
      F(2)=F(2)+RASVOL*CXXJJJ
      F(3)=F(3)+RASVOL*CZZJJJ
      F(4)=F(4)+RASVOL*(CXXJJJ**2+(DL(JJ)*CZETA(JJ))**2*.083333
     ,     +(BC(JJ)*SZETA(JJ))**2*.333333)
      F(5)=F(5)+RASVOL*(CZZJJJ**2+(DL(JJ)*SZETA(JJ))**2*.083333
     ,      +(BC(JJ)*CZETA(JJ))**2*.333333)
      F(6)=F(6)+RASVOL*(CXXJJJ*CZZJJJ+SZETA(JJ)*CZETA(JJ)*
     ,      (DL(JJ)**2*.083333-BC(JJ)**2*.333333))
      CONC(JJ)=0.
      GO TO 430
  460 CONC(JJ)=CONC(JJ)/(2.*BC(JJ)*DL(JJ)*THICK(JJ))
      GO TO 430
  500 IF(METHOD .EQ. 3) GO TO 545
      IF(JJ .LT. INDEX)541,545
  541 POSITN(JJ)=CY(JJ)-SIN(THETA2(JJ))*BC(JJ)+WW(KK)*DT4+.5*THICK(JJ)
      GO TO 549
  545 IF(JJ .LT. INDEX) 546,547
  546 POSITN(JJ)=CY(JJ)-.375*BC(JJ)+WW(KK)*DT4+.5*THICK(JJ)
      GO TO 549
  547 IF(JJ .GT. IBED .AND. JJ .LE. ILEAVE)551,548
  548 POSITN(JJ)=CY(JJ)-AA(JJ)+WW(KK)*DT4+.5*THICK(JJ)
      GO TO 549
  551 POSITN(JJ)=CY(JJ)-1,3*AA(JJ)+WW(KK)*DT4+,5*THICK(JJ)
  549 CONTINUE
      CONC(JJ)=SVOL(JJ)*DT3
      DIST=POSITN(JJ)
      IF(DIST +,5*THICK(JJ) .LE. 0.) GO TO 550
      IF(DIST .GE. .5*THICK(JJ)) GO TO 560
      ENTSURF=,5*THICK(JJ)-DIST
      RATIO=ENTSURF/THICK(JJ)
      RASVOL=RATIO*CONC(JJ)
      CXXJJJ=CX(JJ)-(DT4-0,5*DT3*RATIO)*UBX
      CZZJJJ=CZ(JJ)-(DT4-0,5*DT3*RATIO)*WBZ
      F(1)=F(1)+RASVOL
      F(2)=F(2)+RASVOL*CXXJJJ
      F(3)=F(3)+RASVOL*CZZJJJ
      F(4)=F(4)+RASVOL*(CXXJJJ**2+(DL(JJ)*CZETA(JJ))**2*,083333
     ,      +(BC(JJ)*SZETA(JJ))**2*,333333)
      F(5)=F(5)+RASVOL*(CZZJJJ**2+(DL(JJ)*SZETA(JJ))**2*,083333
     ,       +(BC(JJ)*CZETA(JJ))**2*,333333)
      F(6)=F(6)+RASVOL*(CXXJJJ*CZZJJJ+SZETA(JJ)*CZETA(JJ)*
     ,       (DL(JJ)**2*,083333-BC(JJ)**2*,333333))
      CONC(JJ)=(1,-RATIO)*CONC(JJ)
      THICK(JJ)=(1,-RATIO)*THICK(JJ)
      POSITN(JJ)=  ,501*THICK(JJ)
      CONC(JJ)=CONC(JJ)/(2,*BC(JJ)*DL(JJ)*THICK(JJ))
      GO TO 430
  550 RASVOL=CONC(JJ)
      CXXJJJ=CX(JJ)-(DT4-0,5*DT3)*UBX
      CZZJJJ=CZ(JJ)-(DT4-0,5*DT3)*WBZ
      F(1)=F(1)+RASVOL
      F(2)=F(2)+RASVOL*CXXJJJ
      F(3)=F(3)+RASVOL*CZZJJJ
      F(4)=F(4)+RASVOL*(CXXJJJ**2+(DL(JJ)*CZETA(JJ))**2*,083333
     ,      +(BC(JJ)*SZETA(JJ))**2*,333333)
      F(5)=F(5)+RASVOL*(CZZJJJ**2+(DL(JJ)*SZETA(JJ))**2*,083333
     ,       +(BC(JJ)*CZETA(JJ))**2*,333333)
      F(6)=F(6)+RASVOL*(CXXJJJ*CZZJJJ+SZETA(JJ)*CZETA(JJ)*
     ,       (DL(JJ)**2*,083333-BC(JJ)**2*,333333))
      CONC(JJ)=0,
      GO TO 430
  560 CONC(JJ)=CONC(JJ)/(2,*BC(JJ)*DL(JJ)*THICK(JJ))
  430 CONTINUE
      AVEDT4=SAVDT4/(IEND-ISTART)
      DO 465 JJ=ISTART,IEND
      IF(CONC(JJ) .LE. 0.) GO TO 465
      CALL INDATA2
  465 CONTINUE
      CALL GRIDSA
      CALL INABCD
      CALL INSOL
      TT=TEND
      IF(TEND.GE.T4) GO TO 12346
      KJI=IJK/NOUTPT
      XIJK=IJK
      XXX=XIJK/NOUTPT
      IF(ABS(XXX-KJI).LT.1.E-10) 12346,12345
12346 CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
12345 CONTINUE
      CALL SHIFT
      IF(TEND .GE. T4) GO TO 480
      TSTART=TEND
      TEND=TEND+TGRID
      IF(TSTART .GT. T3) 475,600
  475 DO 476 JJ=ISTART,ISTEP
      IF(TIME +T(JJ) .GE. TSTART) 477,476
  476 CONTINUE
  477 ISTART=JJ
      GO TO 600
  250 CONTINUE
      IF(YY .LE. YK1)YKK=AKY1
      IF(YY .GT. YK1 .AND. YY .LT. YK2)YKK=.5*(AKY1+AKY2)
      IF(YY .GE. YK2 .AND. YY .LE. YK3)YKK=AKY2
      IF(YY .GT. YK3 .AND. YY .LT. YK4)YKK=.5*(AKY2+AKY3)
      IF(YY .GE. YK4) YKK=AKY3
      DT=.004*(4.*A0)**2/YKK
      NGRID1=TIME/DT
      IF(NGRID1 .LE. 0)251,252
  251 AMCVT3=(T4-T2)/DT2
      CALL CONVRT3
      DO 750 I=1,J1
  750 Y1(I)=Y2(I)
      DO 760 I=1,6
      DO 760 J=1,J1
  760 E(I,J)=FE(I,J)
      TT=T4
      CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
      CALL INABCD
      GO TO 480
  252 AMCVT3=DT/DT2
      CALL CONVRT3
      DO 770 I=1,J1
  770 Y1(I)=Y2(I)
      DO 780 I=1,6
      DO 780 J=1,J1
  780 E(I,J)=FE(I,J)
      TT=T2+DT
      CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
      IF(NGRID1.NE. 1) GO TO 253
      AMCVT3=(TIME-DT)/DT2
      DT=AMCVT3*DT2
      CALL INABCD
      CALL MATXCO
      CALL SOLUTN
      CALL SHIFT
      CALL CONVRT3
      CALL ADD
      TT=T4
      CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
      GO TO 480
  253 CONTINUE
      CALL GRIDSA
      CALL INABCD
      CALL INSOL
      CALL MATXCO
      CALL SHIFT
      AMCVT3=DT/DT2
      DO 254 JJ=2,NGRID1
      CALL SOLUTN
      CALL CONVRT3
      CALL ADD
      TT=TT+DT
      IF(JJ.EQ.10*(JJ/10)) 256,254
  256 CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
  254 CONTINUE
      AMCVT3=(TIME-NGRID1*DT)/DT2
      DT=AMCVT3*DT2
      CALL MATXCO
      CALL SOLUTN
      CALL CONVRT3
      CALL ADD
      TT=T4
      CALL OUTPT
      IF(IPLT.EQ.0.AND.NOMOR.EQ.1) GO TO 1000
  480 CONTINUE
      WRITE(6,2) TT
    2 FORMAT(1H1,10X,42H**INPUT TO LONG TERM DIFFUSION COMPLETED** ,/,10
     *X,4HTIME,G12.5,/,1H1)
      NOTE=0
C     NOTE OF COMPUTING SPREADO BEFORE LONG TERM DIFFUSION
      CDT=DTO/IHUG
      NGRID=NGRID3
      ORIGIN=ORIGIN*TIME*50000.
  255 CALL GRIDSR
      CALL INABCD
      CALL MATXCO
      CALL INSOL
      CALL SHIFT
      OTOT=AMO+F(1)
      DO 300 IJ=1,NGRID
      CALL SOLUTN
      TT=TT+DT
  300 CONTINUE
      ZAMO=0.
      DO 9877 I=1,J2
 9877 ZAMO=ZAMO+(F(1,I)+E(1,I+1))*DY(I)*.5
      ZTOT=ZAMO+F(1)
      IF(ZTOT .LE. 0.)GO TO 9878
      RTOT=OTOT/ZTOT
      DO 9879 I=1,J1
 9879 F(1,I)=E(1,I)*RTOT
      F(1)=F(1)*RTOT
 9878 CONTINUE
      CALL OUTPT
      IF(NOMOR.EQ.1) GO TO 1000
      IF(TT .GE. TSTOP) GO TO 1000
      IF (WW(KK))310,320 ,310
  310 IF(AMO .LE. ORIGIN) GO TO 1000
      GO TO 255
  320 VMAX=0.
      VMIN=1000000.
      DO 340 I=1,J1
      IF(F(1,I) .LE. 1.000E-15) GO TO 340
      CONC=E(1,I)/VAR(I)
      IF (VMAX .LT. CONC) VMAX=CONC
      IF( VMIN .GT. CONC) VMIN=CONC
  340 CONTINUE
```

```
      RATIO=VMIN/VMAX
      IF(RATIO .GE. 0.95) GO TO 1000
      GO TO 255
 1000 CONTINUE
      IFINISH=1
      CALL OUTPT
      DO 1003 I=1,ISTEP
      CX(I)=CX(I)+X0
 1003 CZ(I)=CZ(I)+Z0
 1001 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE   MATXCO
C
C     COMPUTE THE ELEMENTS OF A TRI-DIAGONAL MATRIX
C
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,             YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/EE(8,151),
     ,   E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,               CCMAX(151),VAR(151)
      COMMON /MATRIX/ A(151),B(151),C(151),CP(151)
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     , ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     , ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
C
C
      J1=ISIZE
      J2=J1-1
      DDDDT=1./DT
      IF(WW(KK)) 300,400,500
  300 K1=1
      K2=0
      GO TO 101
  400 K1=1
      K2=1
      GO TO 102
  500 K1=0
      K2=1
      GO TO 102
C     MATRIX COEF FOR NEGATIVE FALL VELOCITY
  101 B(1)=-(DDDDT+CKY(1)/DY(1)**2+(K2-K1)*.5*WW(KK)/((K1+K2)*DY(1))
     ,         +(1.-ALFA1)*WW(KK)/DY(1)
     ,         +(1.-ALFA1)*K2*WW(KK)**2/((K1+K2)*CKY(1)))
      C(1)=CKY(1)/DY(1)**2+.5*(K2-K1)*WW(KK)/((K1+K2)*DY(1))
      DO 100 I=2,J2
      WKDY=.5*WW(KK)/(K1*DY(I)+K2*DY(I-1))
      DYI1=1./DY(I-1)
      DYI=1./DY(I)
      DYI1I=1./(DY(I-1)+DY(I))
      A(I)= CKY(I-1)*DYI1*DYI1I
     ,  +K2*WKDY
      B(I)=-(DDDDT+(CKY(I)*DY(I-1)+CKY(I-1)*DY(I))*DYI1*DYI*DYI1I
     ,               +(K2-K1)*WKDY)
  100 C(I)= CKY(I)* DYI*DYI1I
     ,      -K1*WKDY
      A(J1)=CKY(J2)/DY(J2)**2+.5*(K2-K1)*WW(KK)/((K1+K2)*DY(J2))
      B(J1)=-(DDDDT+ CKY(J2)/DY(J2)**2
     ,          +(K2-K1)*.5*WW(KK)/((K1+K2)*DY(J2))
     ,          -WW(KK)/DY(J2)+K1*WW(KK)**2/((K1+K2)*CKY(J2)))
      GO TO 200
C
C     MATRIX COEFF. FOR POSITIVE FALL VELOCITY
  102 B(1)=-(DDDDT+ CKY(1)/DY(1)**2
     ,        +(K2-K1)*.5*WW(KK)/((K1+K2) *DY(1))
     ,         +WW(KK)/DY(1)+K2*WW(KK)**2/((K1+K2)*CKY(1)))
      C(1)=CKY(1)/DY(1)**2+.5*(K2-K1)*WW(KK)/((K1+K2)*DY(1))
      DO 150 I=2,J2
      WKDY=.5*WW(KK)/(K1*DY(I)+K2*DY(I-1))
      DYI1=1./DY(I-1)
      DYI=1./DY(I)
      DYI1I=1./(DY(I-1)+DY(I))
      A(I)= CKY(I-1)*DYI1*DYI1I
     ,  +K2*WKDY
      B(I)=-(DDDDT+(CKY(I)*DY(I-1)+CKY(I-1)*DY(I))*DYI1*DYI*DYI1I
     ,              +(K2-K1)*WKDY)
  150 C(I)= CKY(I)*DYI*DYI1I
     ,      -K1*WKDY
      A(J1)=CKY(J2)/DY(J2)**2
     ,      +.5*(K2-K1)*WW(KK)/((K1+K2)*DY(J2))
      B(J1)=-(DDDDT+ CKY(J2)/DY(J2)**2
     ,          +(K2-K1)*.5*WW(KK)/((K1+K2)*DY(J2))
     ,        -(1.-ALFA2)*WW(KK)/DY(J2)
     ,          +K1*(1.-ALFA2)*WW(KK)**2/((K1+K2)*CKY(J2)))
  200 CONTINUE
      C(J1)=0.
      CP(1)=C(1)/B(1)
      DO 220 J=1,J2
      DENO=B(J+1)-A(J+1)*CP(J)
  220 CP(J+1)=C(J+1)/DENO
      RETURN
      END
vv
```

```
      SUBROUTINE   SOLUTN
C
C     SOLUTION BY THOMAS ALGORITHM
C
      DIMENSION DP(151),D(151),SOL(151)
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON        CX(600),CY(600),AA    (600),U(600),
     ,     V(600), ALOW(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,              CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /MATRIX/ A(151),B(151),C(151),CP(151)
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,TBED,ILEAVE
     ,  ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
      COMMON/CNOMOR/NOMOR,TPLOT
      BUX=UBX
      BWZ=WBZ
      IF(TT .LT. TPLOT) GO TO 4004
      BUX=0.
      BWZ=0.
 4004 CONTINUE
      J1=ISIZE
      J2=J1-1
      DDDDT=1./DT
      W=WW(KK)
      DO 993 J=1,J1
      E(7,J)=E(4,J)
  993 E(8,J)=E(5,J)
      F(7)=F(4)
      F(8)=F(5)
      DO 998 I=1,8
      VAR(I)=F(I)
      DO 998 J=1,J1
  998 EE(I,J)=E(I,J)
      IF(W) 995,996,997
  995 K1=1
      K2=0
      GO TO 999
  996 K1=1
      K2=1
      GO TO 994
  997 K1=0
      K2=1
C     SOLUTION FOR POSITIVE FALL VEL.
  994 DO 1000 I=1,8
      GO TO (1,2,3,4,5,6,7,8),I
    1 DO 101 J=1,J1
  101 D(J)=0.
      FW(I)=0.
      GO TO 200
  2   DO 102 J=1,J1
 102  D(J)=-UA(J)*(E(1,J)+EE(1,J))*0.5
      FW(I)=-BUX*(F(1)+VAR(1))*.5
      GO TO 200
  3   DO 103 J=1,J1
 103  D(J)=-WA(J)*(E(1,J)+EE(1,J))*0.5
      FW(I)=-BWZ*(F(1)+VAR(1))*.5
      GO TO 200
  4   DO 104 J=1,J1
 104  D(J)=-(UA(J)*(E(2,J)+EE(2,J))+DISPC(ALAMDA,J)*(E(1,J)+EE(1,J)))
      FW(I)=-BUX*(F(2)+VAR(2))
      GO TO 200
  5   DO 105 J=1,J1
 105  D(J)=-(WA(J)*(E(3,J)+EE(3,J))+DISPC(ALAMDA,J)*(E(1,J)+EE(1,J)))
      FW(I)=-BWZ*(F(3)+VAR(3))
      GO TO 200
  6   DO 106 J=1,J1
 106  D(J)=-(UA(J)*(E(3,J)+EE(3,J))+WA(J)*(E(2,J)+EE(2,J)))*0.5
      FW(I)=-(BUX*(F(3)+VAR(3))+BWZ*(F(2)+VAR(2)))*.5
      GO TO 200
   7  DO 107 J=1,J1
 107  D(J)=-(UA(J)*(E(2,J)+EE(2,J))+DISPCC(ALAMDA,J)*(E(1,J)+EE(1,J)))
      FW(I)=-BUX*(F(2)+VAR(2))
      GO TO 200
   8  DO 108 J=1,J1
 108  D(J)=-(WA(J)*(E(3,J)+EE(3,J))+DISPCC(ALAMDA,J)*(E(1,J)+EE(1,J)))
      FW(I)=-BWZ*(F(3)+VAR(3))
 200  F(I) =F(I)+(FW(I)+ALFA2*W*E(I,J1)-GAMA2*F(I))*DT
      D(1)=D(1)-((CKY(1)/DY(1)**2+.5*(K2-K1)*W/((K1+K2)*DY(1))))*E(I,2)
     ,-(DDDDT-CKY(1)/DY(1)**2-(K2-K1)*.5*W/((K1+K2)*DY(1))
     ,       -W/DY(1)-K2*W**2/((K1+K2)*CKY(1)))*E(I,1)
      DO 210 J=2,J2
      WDY=.5*W/(K1*DY(J)+K2*DY(J-1))
      DYJ=1./DY(J)
      DYJ1=1./DY(J-1)
      DYJ1J=1./(DY(J)+DY(J-1))
 210  D(J)=D(J)-( CKY(J)*DYJ*DYJ1J
     ,        -K1*WDY                           )*E(I,J+1)
     ,-(DDDDT = (CKY(J-1)*DY(J)+CKY(J)*DY(J-1))*DYJ*DYJ1*DYJ1J
     ,            -(K2-K1)*WDY                          )*E(I,J)
     ,-( CKY(J-1)*DYJ1*DYJ1J
     ,        +K2*WDY                           )*E(I,J-1)
      D(J1)=D(J1)-((CKY(J2)/DY(J2)**2
     ,              +.5*(K2-K1)*W/((K1+K2)*DY(J2))))*E(I,J2)
     ,  -(DDDDT -CKY(J2)/DY(J2)**2
     ,          -.5*(K2-K1)*W/((K1+K2)*DY(J2))
     ,         +(1.-ALFA2)*W/DY(J2)
     ,         -K1*(1.-ALFA2)*W**2/((K1+K2)*CKY(J2)))*F(I,J1)
     ,   -(1./DY(J2)-K1*W/((K1+K2)*CKY(J2)))*GAMA2*(F(I)+VAR(I))
      DP(1)=D(1)/B(1)
      DO 220 J=1,J2
      DENO=B(J+1)-A(J+1)*CP(J)
 220  DP(J+1)=(D(J+1)-A(J+1)*DP(J))/DENO
      SOL(J1)=DP(J1)
      DO 230 J=1,J2
      JP=J2-J+1
 230  SOL(JP)=DP(JP)-CP(JP)*SOL(JP+1)
      DO 300 J=1,J1
 300  E(I,J)=SOL(J)
 1000 CONTINUE
      GO TO 1001
C     SOLUTION FOR NEGATIVE FALL VEL.
  999 DO 10000 I=1,8
      GO TO (10,20,30,40,50,60,70,80),I
   10 FW(I)=0.
      DO 1010 J=1,J1
 1010 D(J)=0.
      GO TO 2000
   20 FW(I)=UA(1)*(F(1)+VAR(1))*0.5
      DO 1020 J=1,J1
 1020 D(J)=-UA(J)*(E(1,J)+EF(1,J))*0.5
      GO TO 2000
   30 FW(I)=WA(1)*(F(1)+VAR(1))*0.5
      DO 1030 J=1,J1
 1030 D(J)=-WA(J)*(F(1,J)+EE(1,J))*0.5
      GO TO 2000
   40 FW(I)=(UA(1)*(F(2)+VAR(2))+DISPW(ALAMDA)*(F(1)+VAR(1)))
      DO 1040 J=1,J1
 1040 D(J)=-(UA(J)*(F(2,J)+FE(2,J))+DISPC(ALAMDA,J)*(F(1,J)+EE(1,J)))
      GO TO 2000
   50 FW(I)=1.*(WA(1)*(F(3)+VAR(3))+DISPW(ALAMDA)*(F(1)+VAR(1)))
      DO 1050 J=1,J1
 1050 D(J)=-1.*(WA(J)*(F(3,J)+EE(3,J))+DISPC(ALAMDA,J)*(E(1,J)+EF(1,J)))
      GO TO 2000
   60 FW(I)=(UA(1)*(F(3)+VAR(3))+WA(1)*(F(2)+VAR( 2)))*0.5
      DO 1060 J=1,J1
 1060 D(J)=-(UA(J)*(F(3,J)+FF(3,J))+WA(J)*(E(2,J)+EF(2,J)))*0.5
      GO TO 2000
   70 FW(I)=(UA(1)*(F(2)+VAR(2))+DISPWW(ALAMDA)*(F(1)+VAR(1)))
      DO 1070 J=1,J1
 1070 D(J)=-(UA(J)*(F(2,J)+EE(2,J))+DISPCC(ALAMDA,J)*(E(1,J)+FE(1,J)))
      GO TO 2000
   80 FW(I)=1.*(WA(1)*(F(3)+VAR(3))+DISPWW(ALAMDA)*(F(1)+VAR(1)))
      DO 1080 J=1,J1
 1080 D(J)=-1.*(WA(J)*(E(3,J)+EF(3,J))+DISPCC(ALAMDA,J)*(E(1,J)+FE(1,J))
     , )
 2000 F(I) =F(I)+(FW(I)-ALFA1*W*E(I,1)-GAMA1*F(I))*DT
      D(1)=D(1)-(1./DY(1)+K2*W/((K1+K2)*CKY(1)))*GAMA1*(VAR(I)+F(I))
     ,       -(CKY(1)/DY(1)**2+.5*(K2-K1)*W/((K1+K2)*DY(1)))*E(I,2)
     ,       -(DDDDT-CKY(1)/DY(1)**2-(1.-ALFA1)*W/DY(1)
     ,    -(K2-K1)*.5*W/((K1+K2)*DY(1))
     ,     -(1.-ALFA1)*K2*W**2/CKY(1))*E(I,1)
      DO 2100 J=2,J2
      WDY=.5*W/(K1*DY(J)+K2*DY(J-1))
      DYJ=1./DY(J)
      DYJ1=1./DY(J-1)
      DYJ1J=1./(DY(J)+DY(J-1))
 2100 D(J)=D(J)-( CKY(J)*DYJ*DYJ1J
     ,       -K1*WDY                                  )*F(I,J+1)
     ,-(DDDDT - (CKY(J-1)*DY(J)+CKY(J)*DY(J-1))*DYJ*DYJ1*DYJ1J
     ,          -(K2-K1)*WDY                                  )*E(I,J)
     ,-( CKY(J-1)*DYJ1*DYJ1J
     ,        +K2*WDY                                 )*F(I,J-1)
      D(J1)=D(J1)-(CKY(J2)/DY(J2)**2+.5*(K2-K1)*W/((K1+K2)*DY(J2)))
     ,        *E(I,J2)
     ,      -(DDDDT+W/DY(J2)-CKY(J2)/DY(J2)**2
     ,       -.5*(K2-K1)*W/((K1+K2)*DY(J2))
     ,        -K1*W**2/((K1+K2)*CKY(J2)))*F(I,J1)
      DP(1)=D(1)/B(1)
      DO 2200 J=1,J2
      DENO=B(J+1)-A(J+1)*CP(J)
 2200 DP(J+1)=(D(J+1)-A(J+1)*DP(J))/DENO
      SOL(J1)=DP(J1)
      DO 2300 J=1,J2
      JP=J2-J+1
 2300 SOL(JP)=DP(JP)-CP(JP)*SOL(JP+1)
      DO 3000 J=1,J1
 3000 E(I,J)=SOL(J)
10000 CONTINUE
 1001 CONTINUE
      DO 1002 J=1,J1
      E(4,J)=.5*(E(4,J)+E(7,J))
 1002 E(5,J)=.5*(E(5,J)+E(8,J))
      F(4)=.5*(F(4)+F(7))
      F(5)=.5*(F(5)+F(8))
      RETURN
      END
vv
```

```
      SUBROUTINE   GRIDSA
C
C     COMPUTE THE GRID SIZE ACCORDING TO THE SPREADING OF THE CLOUD
C
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,AMCVT3
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,                YU,YW,YF,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBFD,ILEAVE
     ,  ,IJK,FBFD,AM0,DLDT,METHOD,TSTOP
      J1=ISIZE
      J2=J1-1
      J3=4*J2/10
      J4=J2-J3
      NGRID=1
      AM0=0.
      AM1=0.
      AM2=0.
      DO 170 I=1,J2
      AM0=AM0+(E(1,I)+E(1,I+1))*DY(I)*.5
      AM1=AM1+(Y1(I)*E(1,I)+Y1(I+1)*E(1,I+1))*DY(I)*.5
      AM2=AM2+(Y1(I)**2*E(1,I)+Y1(I+1)**2*E(1,I+1))*DY(I)*.5
  170 CONTINUE
      IF(AM0 .EQ. 0.)GO TO 230
      YBAR=AM1/AM0
      SPREAD=2.*SQRT(AM2/AM0-YBAR**2)
      YL=YBAR-SPREAD
      IF(YL .LE. 0.)YL=0.
      YH=YBAR+SPREAD
      IF(YH .GE. H)YH=H
      SPREAD=.5*(YH-YL)
      YBAR=YL+SPREAD
      IF(WW(KK) .LT. 0.)GO TO 550
      IF(H -(YBAR+SPREAD+WW(KK)*NGRID*DT)   .LT. 0.)500,600
  500 DH=(H-(YBAR-SPREAD))/J3
      GO TO 650
  550 IF(YBAR-SPREAD+WW(KK) *NGRID*DT  .LT. 0.)560,600
  560 DH=(YBAR+SPREAD)/J3
      GO TO 650
  600 DH=(2.*SPREAD+ABS(WW(KK))*NGRID*DT)/J3
  650 DDDH=1./DH
      IF (WW(KK) .LT.0.) GO TO 300
      N2=(H-(YBAR+SPREAD   +WW(KK)*NGRID *DT))*DDDH
      IF (N2 .LT. 0) N2=0
      N1=(YBAR-SPREAD    )*DDDH
      IF(N1 .LE. 0) N1=0
      NN=N1+N2
      IF (NN .LT. J4) GO TO 210
      M1=N1*J4/NN
      M2=J4-M1
      IF (M2 .EQ. 0) GO TO 171
      BB=(H-(YBAR+SPREAD+WW(KK)*NGRID*DT)-M2*DH)*2./(M2*DH*(M2+1))
  171 IF(M1 .EQ. 0) GO TO 400
      AA =(YBAR-SPREAD   -M1*DH)*2./(M1*DH*(M1+1))
      GO TO 400
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```
300 N1=(YBAR-SPREAD    +WW(KK)*NGRID*DT)*DDDH
    IF (N1 .LE. 0) N1=0
    N2=(H-(YBAR+SPREAD    ))*DDDH
    IF(N2 .LE. 0) N2=0
    NN=N1+N2
    IF (NN .LT. J4) GO TO 210
    M1=N1*J4/NN
    M2=J4-M1
    IF (M1 .EQ. 0) GO TO 301
    AA =(YBAR-SPREAD    +WW(KK)*NGRID*DT-M1*DH)*2./(M1*DH*(M1+1))
301 IF(M2 .EQ. 0) GO TO 400
    BB =(H-(YBAR+SPREAD    )-M2*DH)*2./(M2*DH*(M2+1))
400 Y2(1)=0.
    IF (M1 .EQ.0) GO TO 181
    DO 180 I=1,M1
    IJ=M1-I+1
    DY(I)=(IJ*AA+1)*DH
    Y2(I+1)=Y2(I)+DY(I)
180 CONTINUE
181 CONTINUE
    DO 190 I=1,J3
    Y2(M1+1+I)=Y2(M1+I)+DH
    DY(M1+I)=DH
190 CONTINUE
    IF (M2 .EQ. 0) GO TO 230
    DO 200 I=1, M2
    DY(M1+J3+I)=(I *BB+1)*DH
    Y2(M1+J3+I+1)=Y2(M1+J3+I)+DY(M1+J3+I)
200 CONTINUE
    GO TO 230
210 DH=H/J2
    Y2(1)=0.
    DO 220 I=1,J2
    Y2(I+1)=Y2(I)+DH
    DY(I)=DH
220 CONTINUE
230 CONTINUE
    RETURN
    END
vv
```

```
      SUBROUTINE    GRIDSB
      COMMON /COMPUT/EF(8,151),
     ,     E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,                YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C     COMPUTE THE GRID AND TIME INTERVAL ACCORDING TO THE SPREADING
C     OF THE CLOUD
C
      J1=ISIZE
      J2=J1-1
      J3=4*J2/10
      J4=J2-J3
      AM0=0.
      AM1=0.
      AM2=0.
      DO 100 I=1,J2
      AM0=AM0+(E(1,I)+E(1,I+1))*DY(I)*.5
      AM1=AM1+(Y1(I)*E(1,I)+Y1(I+1)*E(1,I+1))*DY(I)*.5
      AM2=AM2+(Y1(I)**2*E(1,I)+Y1(I+1)**2*E(1,I+1))*DY(I)*.5
  100 CONTINUE
      YBAR=AM1/AM0
      SPREAD=2.*SQRT(AM2/AM0-YBAR**2)
      PSN1=YBAR-SPREAD
      IF(PSN1 .LE. 0.) PSN1=0.
      PSN2=YBAR+SPREAD
      IF(PSN2 .GE. H) PSN2=H
      DO 210 I=1,J1
      IF (PSN1 - Y1(I))  220,220,210
  210 CONTINUE
  220 I1=I
      DO 230 J=I1,J1
      IF (PSN2 - Y1(J)) 240,240,230
  230 CONTINUE
  240 I2=J-1
      VMAX=0.
      DO 250 I=I1,I2
      IF (VMAX .LT. CKY(I))  VMAX=CKY(I)
  250 CONTINUE
      SPREAD=(PSN2-PSN1)*.5
      YBAR=PSN1+SPREAD
      IF(NOTE .EQ. 0)SPREAD0=SPREAD
      NOTE=NOTE+1
      IF (WW(KK)) 101,200,101
  101 IF(SPREAD .LT. SPREAD0) GO TO 500
      DT3=.02*SPREAD/(ABS(WW(KK)))
      IF(DT3 .GT. CDT)DT3=CDT
      DT4=.004*SPREAD**2/VMAX
      IF(DT3-DT4)201,201,202
  201 DT=DT3
      GO TO 262
  202 DT=DT4
      GO TO 262
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 200 DT=.004*SPREAD**2/VMAX
 262 CONTINUE
     IF(WW(KK) .LT. 0.)GO TO 550
     IF(H -(YBAR+SPREAD+WW(KK)*NGRID*DT)   .LT. 0.)510,600
 510 DH=(H-(YBAR-SPREAD))/J3
     GO TO 650
 550 IF(YBAR-SPREAD+WW(KK) *NGRID*DT  .LT. 0.)560,600
 560 DH=(YBAR+SPREAD)/J3
     GO TO 650
 600 DH=(2.*SPREAD+ABS(WW(KK))*NGRID*DT)/J3
 650 DDDH=1./DH
     IF (WW(KK) .LT.0.) GO TO 300
     N2=(H-(YBAR+SPREAD   +WW(KK)*NGRID *DT))*DDDH
     IF (N2 .LT. 0) N2=0
     N1=(YBAR-SPREAD   )*DDDH
     IF(N1 .LE. 0) N1=0
     NN=N1+N2
     IF (NN .LT. J4) GO TO 310
     M1=N1*J4/NN
     M2=J4-M1
     IF (M2 .EQ. 0) GO TO 261
     DH2=(H-(YBAR+SPREAD   +WW(KK)*NGRID *DT)-M2*DH)*2./(M2*DH*(M2+1))
 261 IF(M1 .EQ. 0) GO TO 400
     DH1=(YBAR-SPREAD   -M1*DH)*2./(M1*DH*(M1+1))
     GO TO 400
 300 N1=(YBAR-SPREAD   +WW(KK)*NGRID*DT)*DDDH
     IF (N1 .LE. 0) N1=0
     N2=(H-(YBAR+SPREAD   ))*DDDH
     IF(N2 .LE. 0)N2=0
     NN=N1+N2
     IF (NN .LT. J4) GO TO 310
     M1=N1*J4/NN
     M2=J4-M1
     IF (M1 .EQ. 0) GO TO 301
     DH1=(YBAR-SPREAD   +WW(KK)*NGRID*DT-M1*DH)*2./(M1*DH*(M1+1))
 301 IF( M2 .EQ. 0) GO TO 400
     DH2=(H-(YBAR+SPREAD   )   -M2*DH)*2./(M2*DH*(M2+1))
 400 Y2(1)=0.
     IF (M1 .EQ.0) GO TO 411
     DO 410 I=1, M1
     IJ=M1-I+1
     DY(I)=(IJ*DH1+1)*DH
     Y2(I+1)=Y2(I)+DY(I)
 410 CONTINUE
 411 CONTINUE
     DO 420 I=1,J3
     Y2(M1+1+I)=Y2(M1+I)+DH
     DY(M1+I)=DH
 420 CONTINUE
     IF (M2 .EQ. 0) GO TO 500
     DO 430 I=1, M2
     DY(M1+J3+I)=(I *DH2+1)*DH
     Y2(M1+J3+I+1)=Y2(M1+J3+I)+DY(M1+J3+I)
 430 CONTINUE
     GO TO 500
 310 DH=H/J2
     Y2(1)=0.
     DO 320 I=1,J2
     Y2(I+1)=Y2(I)+DH
     DY(I)=DH
```

```
  320 CONTINUE
  500 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE INDATA1
C
C     INTERPOLATE DATA ON SOLIDS FROM CONVECTIVE DESCENT PHASE OR
C     DYNAMIC COLLAPSE PHASE TO GRID Y1 SUITABLE FOR LONG TERM DIFFUSION
C     COMPUTATION
C
      COMMON /C/X0,Z0
      COMMON /COMPUT/EF(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRIDS,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON             CX(600),CY(600),AA    (600),U(600),
     ,     V(600),    W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,               CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,               UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IRED,ILEAVE
     ,  ,IJK,FRED,AM0,DLDT,METHOD,TSTOP
C
C
C
C
      J1=ISIZE
      J2=J1-1
      PSN1=POSITN(JJ)-THICK(JJ)*.5
      PSN2=POSITN(JJ)+THICK(JJ)*.5
      IF(PSN2 .GT. Y1(J1)) PSN2=Y1(J1)
      DO  100 I=1,J1
      IF (PSN1-Y1(I)) 110,100,100
  100 CONTINUE
      I=J1
  110 DO 150 J=I,J1
      IF (PSN2-Y1(J))   120,120,130
  130 MORE=1
      POS2=Y1(J)
      GO TO 140
  120 MORE=0
      POS2=PSN2
  140 CENTER=(PSN1+POS2)*.5
      IF(J .EQ. 2 .OR. J .EQ. J1) 141,142
  141 IF(J .EQ. 2) 143,144
  143 DENO= (Y1(J)-CENTER)*(        DY(J-1))
     ,       +(CENTER-Y1(J-1))*(DY(J-1)+DY(J))
      GO TO 145
  144 DENO= (Y1(J)-CENTER)*(DY(J-2)+DY(J-1))
     ,       +(CENTER-Y1(J-1))*(DY(J-1)        )
      GO TO 145
  142 DENO= (Y1(J)-CENTER)*(DY(J-2)+DY(J-1))
     ,       +(CENTER-Y1(J-1))*(DY(J-1)+DY(J))
  145 A1=2.*(Y1(J)-CENTER)/DENO
      A2=2.*(CENTER-Y1(J-1))/DENO
      AREA=PAI*CB(JJ)**2
      RR  =       SVOL( JJ)*AREA*(POS2-PSN1)
      RRA1=RR*A1
      RRA2=RR*A2
      E(1,J-1)=E(1,J-1)+RRA1
      XCC=XC(JJ)
      ZCC=ZC(JJ)
      E(2,J-1)=E(2,J-1)+RRA1*XCC
      E(3,J-1)=E(3,J-1)+RRA1*ZCC
      E(4,J-1)=E(4,J-1)+RRA1*(XCC   **2+CB(JJ)**2*.25)
      E(5,J-1)=E(5,J-1)+RRA1*(ZCC   **2+CB(JJ)**2*.25)
      E(6,J-1)=E(6,J-1)+RRA1*XCC   *ZCC
      E(1,J)=E(1,J)+RRA2
      E(2,J)=E(2,J)+RRA2*XCC
      E(3,J)=E(3,J)+RRA2*ZCC
      E(4,J)=E(4,J)+RRA2*(XCC   **2+CB(JJ)**2*.25)
      E(5,J)=E(5,J)+RRA2*(ZCC   **2+CB(JJ)**2*.25)
      E(6,J)=E(6,J)+RRA2*XCC   *ZCC
      IF (MORE .EQ. 0 ) GO TO 160
      PSN1=Y1(J)
  150 CONTINUE
  160 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE INDATA2
C
C     INTERPOLATE DATA ON SOLIDS FROM PLUME OR JET TO GRID Y1 FOR LONG
C     TERM DIFFUSION
C
      COMMON /C/X0,Z0
      COMMON /COMPUT/FF(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,     ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON            CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),   DTT(600),   DL(600),
     ,                CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600), T(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),CONC (600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
      COMMON/SHCAKE/AVEDT4
C
C
      J1=ISIZE
      J2=J1-1
      PSN1=POSITN(JJ)-THICK(JJ)*.5
      PSN2=POSITN(JJ)+THICK(JJ)*.5
      IF(PSN2 .GT. Y1(J1)) PSN2=Y1(J1)
      DO  100 I=1,J1
      IF (PSN1-Y1(I)) 110,100,100
  100 CONTINUE
      I=J1
  110 DO 150 J=I,J1
      IF (PSN2-Y1(J))   120,120,130
  130 MORE=1
      POS2=Y1(J)
      GO TO 140
  120 MORE=0
      POS2=PSN2
  140 CENTER=(PSN1+POS2)*.5
      IF(J .EQ. 2 .OR. J .EQ. J1) 141,142
  141 IF(J .EQ. 2) 143,144
  143 DENO= (Y1(J)-CENTER)*(          DY(J-1))
     ,         +(CENTER-Y1(J-1))*(DY(J-1)+DY(J))
      GO TO 145
  144 DENO= (Y1(J)-CENTER)*(DY(J-2)+DY(J-1))
     ,         +(CENTER-Y1(J-1))*(DY(J-1)        )
      GO TO 145
  142 DENO= (Y1(J)-CENTER)*(DY(J-2)+DY(J-1))
     ,         +(CENTER-Y1(J-1))*(DY(J-1)+DY(J))
  145 A1=2.*(Y1(J)-CENTER)/DENO
      A2=2.*(CENTER-Y1(J-1))/DENO
      AREA=2.*BC(JJ)*DL(JJ)
      RR  =        CONC( JJ)*AREA*(POS2-PSN1)
      RRA1=RR*A1
      RRA2=RR*A2
      CXX=CX(JJ)-AVEDT4        *0.5*UBX
      CZZ=CZ(JJ)-AVEDT4        *0.5*WBZ
      E(1,J-1)=E(1,J-1)+RRA1
      E(2,J-1)=E(2,J-1)+RRA1*CXX
      E(3,J-1)=E(3,J-1)+RRA1*CZZ
      E(4,J-1)=E(4,J-1)+RRA1*(CXX   **2+(DL(JJ)*CZETA(JJ))**2*.083333
     ,        +(BC(JJ)*SZETA(JJ))**2*.333333)
      E(5,J-1)=E(5,J-1)+RRA1*(CZZ   **2+(DL(JJ)*SZETA(JJ))**2*.083333
     ,    +(BC(JJ)*CZETA(JJ))**2*.333333)
      E(6,J-1)=E(6,J-1)+RRA1*(CXX   *CZZ   +SZETA(JJ)*CZETA(JJ)
     ,       *(DL(JJ)**2*.083333-BC(JJ)**2*.333333))
      E(1,J)=E(1,J)+RRA2
      E(2,J)=E(2,J)+RRA2*CXX
      E(3,J)=E(3,J)+RRA2*CZZ
      E(4,J)=E(4,J)+RRA2*(CXX   **2+(DL(JJ)*CZETA(JJ))**2*.083333
     ,      +(BC(JJ)*SZETA(JJ))**2*.333333)
      E(5,J)=E(5,J)+RRA2*(CZZ   **2+(DL(JJ)*SZETA(JJ))**2*.083333
     ,      +(BC(JJ)*CZETA(JJ))**2*.333333)
      E(6,J)=E(6,J)+RRA2*(CXX   *CZZ   +SZETA(JJ)*CZETA(JJ)*
     ,            (DL(JJ)**2*.083333-BC(JJ)**2*.333333))
      IF (MORE .EQ. 0 ) GO TO 160
      PSN1=Y1(J)
  150 CONTINUE
  160 CONTINUE
      RETURN
      END
VV
```

```
      SUBROUTINE  CONVRT2
C
C     CONVERT DATA FROM DYNAMIC COLLAPSE TO DATA FOR LONG TERM DIFFUSION
C
      COMMON /C/X0,Z0
      COMMON /COMPUT/EE(8,151),
     ,    F(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON           CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,                 CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                 UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NUTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      D=A0
      IF(YY+D .GE. H) YY=H-D
      J1=ISIZE
      J2=J1-1
      J3=2*J2/10
      J4=2*J3
      J5=J2-J4
      DH=D/J3
C     D INDICATES THE MINOR AXIS OF THE CLOUD
      PN1=YY-D
      PN2=H-(YY+D)
      N1=PN1/DH
      IF(N1 .LE. 0)N1=0
      N2=PN2/DH
      IF(N2 .LE. 0)N2=0
      NN=N1+N2
      IF(NN .LE. J5) GO TO 500
      M1=J5*N1/NN
      M2=J5-M1
      IF(M1 .EQ. 0) GO TO 90
      AA=(PN1-M1*DH)*2./(M1*DH*(M1+1))
   90 IF(M2 .EQ. 0) GO TO 91
      BB=(PN2-M2*DH)*2./(M2*DH*(M2+1))
   91 Y2(1)=0.
      IF( M1  .EQ. 0 ) GO TO 111
      DO 100 I=1,M1
      IJ=M1-I+1
      DY(I)=(AA*IJ+1)*DH
      Y2(I+1)=Y2(I)+DY(I)
  100 CONTINUE
  111 CONTINUE
      DO 200 I=1,J4
      Y2(I+1+M1)=Y2(I+M1 )+DH
      DY(I+M1)=DH
```

```
200 CONTINUE
    IF (M2 .EQ. 0) GO TO 301
    DO 300 I=1,M2
    DY(I+M1+J4)=(I *HH+1)*DH
    Y2(I+M1+J4+1)=Y2(I+M1+J4)+DY(I+M1+J4)
300 CONTINUE
    GO TO 301
500 DH=H/J2
    Y2(1)=0.
    DO 501 I=2,J1
    Y2(I)=Y2(I-1)+DH
501 CONTINUE
301 CONC=CMAX(KK)
    CXX=CX(ISTEP)
    CZZ=CZ(ISTEP)
    DO 400 I=1,J1
    IF(ABS(Y2(I)-YY) .GE. D) GO TO 410
    AREA=PAI*BC(ISTEP)**2*(1.-((YY-Y2(I))/D)**2)
    RSQ=AREA/PAI
    EE(1,I)=CONC*AREA
    EE(2,I)=EE(1,I)*CXX
    EE(3,I)=EE(1,I)*CZZ
    EE(4,I)=EE(1,I) *(CXX       **2+RSQ*.25)
    EE(5,I)=EE(1,I) *(CZZ       **2+RSQ*.25)
    EE(6,I)=EE(1,I)*CXX       *CZZ
    GO TO 400
410 DO 420 KRCY=1,6
    EE(KRCY,I)=0.
420 CONTINUE
400 CONTINUE
    RETURN
    END
vv
```

```
      SUBROUTINE  CONVRT3
C
C     CONVERT DATA FROM END OF PLUME TO DATA FOR LONG TERM DIFFUSION
C
      COMMON /C/X0,Z0
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,AMCVT3
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON           CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AB  (600),   DTT(600),   DL(600),
     ,                 C7(600),SS(8,  600),
     ,      SVOL(600),XC(600),ZC(600),POSITN(600), T(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),XXXX (600),
     ,    BC(600),WS(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                 UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,                YU,YW,YF,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,TY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
C
C
      D=A0
      IF(YY+D .GE. H) YY=H-D
      J1=ISIZE
      J2=J1-1
      J3=4*J2/10
      J4=2*J3
      J5=J2-J4
      DH=D/J3
C     D INDICATES THE MINOR AXIS OF THE CLOUD
      PN1=YY-D
      PN2=H-(YY+D)
      N1=PN1/DH
      IF(N1 .LE. 0)N1=0
      N2=PN2/DH
      IF(N2 .LE. 0)N2=0
      NN=N1+N2
      IF(NN .LE. J5) GO TO 500
      M1=J5*N1/NN
      M2=J5-M1
      IF(M1 .EQ. 0) GO TO 90
      AA=(PN1-M1*DH)*2./(M1*DH*(M1+1))
   90 IF(M2 .EQ. 0) GO TO 91
      BB=(PN2-M2*DH)*2./(M2*DH*(M2+1))
   91 Y2(1)=0.
      IF( M1  .EQ. 0 ) GO TO 111
      DO 100 I=1,M1
      IJ=M1-I+1
      DY(I)=(AA*IJ+1)*DH
      Y2(I+1)=Y2(I)+DY(I)
  100 CONTINUE
  111 CONTINUE
      DO 200 I=1,J4
      Y2(I+1+M1)=Y2(I+M1 )+DH
      DY(I+M1)=DH
```

```
 200 CONTINUE
     IF (M2 .EQ. 0) GO TO 301
     DO 300 I=1,M2
     DY(I+M1+J4)=(I *BB+1)*DH
     Y2(I+M1+J4+1)=Y2(I+M1+J4)+DY(I+M1+J4)
 300 CONTINUE
     GO TO 301
 500 DH=H/J2
     Y2(1)=0.
     DO 501 I=2,J1
     Y2(I)=Y2(I-1)+DH
 501 CONTINUE
 301 CONC=CMAX(KK)
     DLL=AMCVT3*DL(ISTEP)
     CXX=CX(ISTEP)+.5*(DLL-DL(ISTEP))*CZETA(ISTEP)
     CZZ=CZ(ISTEP)+.5*(DLL -DL(ISTEP))*SZETA(ISTEP)
     DO 400 I=1,J1
     IF(ABS(Y2(I)-YY) .GE. D) GO TO 410
     CC=SQRT(1.-((YY-Y2(I))/D)**2)
     AREA=2.*BC(ISTEP)*DL(ISTEP)*CC
     BCCC=BC(ISTEP)*CC
     EE(1,I)=CONC*AREA*AMCVT3
     EE(2,I)=EE(1,I)*CXX
     EE(3,I)=EE(1,I)*CZZ
     EE(4,I)=EE(1,I) *(CXX       **2+(DLL       *CZETA(ISTEP))**2*.083333
    ,      +(BCCC      *SZETA(ISTEP))**2*.333333)
     EE(5,I)=EE(1,I) *(CZZ       **2+(DLL       *SZETA(ISTEP))**2*.083333
    ,    +(BCCC      *CZETA(ISTEP))**2*.333333)
     EE(6,I)=EE(1,I)*(CXX       *CZZ       +SZETA(ISTEP)*CZETA(ISTEP)
    ,      *(DLL       **2*.083333-BCCC       **2*.333333))
     GO TO 400
 410 DO 420 KRCY=1,6
     EE(KRCY,I)=0.
 420 CONTINUE
 400 CONTINUE
     RETURN
     END
VV
```

```
      SUBROUTINE SUMABCD
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/EE(8,151),
     ,    F(8,151),Y1(151),Y2(151),DY(150),E(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON        CX(600),CY(600),AA    (600),U(600),
     ,     V(600),    W(600),VORT(600),DENDIF(600),FNTRCO(600),
     ,              CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AM0,DLDT,METHOD,TSTOP
      J1=ISIZE
      SUA(1)=0.
      SWA(1)=0.
      SCKY(1)=0.
      DO 100 I=2,J1
      SUA(I)=SUA(I-1)+(UA(I-1)+UA(I))*DY(I-1)*.5
      SWA(I)=SWA(I-1)+(WA(I-1)+WA(I))*DY(I-1)*.5
      SCKY(I)=SCKY(I-1)+(CKY(I-1)+CKY(I))*DY(I-1)*.5
  100 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE  INABCD
C
C     INTERPOLATE THE AMBIENT CONDITIONS TO Y2 GRID
C
      COMMON /ABCD/ Y( 30),ROA( 30),YK1,YK2,YK3,YK4,AKY1,AKY2,AKY3,
     ,              YU,YW,YE,H,UA0,WA0,N,CKY(151),UA(151),WA(151)
      COMMON /COMPUT/FF(8,151),
     ,    F(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,              CCMAX(151),VAR(151)
      COMMON        CX(600),CY(600),AA    (600),U(600),
     ,     V(600),    W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,              CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),T(600),K,L,TPLONG,NOTRL,UB,SAI,TIME,ISTEP,  VF,
     ,              UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,AO,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
      COMMON/CNOMOR/NOMOR,TPLOT
C
      J1=ISIZE
      J2=J1-1
      DO 170 I=1,J1
      UA(I)=0.
      IF (Y2(I) .LE. YU) UA(I)=UA0
      IF (Y2(I) .GT. YU .AND. Y2(I) .LT. YE) UA(I)=(YE-Y2(I))*UA0/
     ,(YE-YU)
      WA(I)=0.
      IF (Y2(I) .LE. YW) WA(I)=       Y2(I)*WA0/YW
      IF (Y2(I) .GT. YW .AND. Y2(I) .LT. YE) WA(I)=(YE-Y2(I))*WA0/(YE-YW
     ,)
      IF (Y2(I) .LE. YK1) CKY(I)=AKY1
      IF (Y2(I) .GT. YK1 .AND. Y2(I) .LT. YK2) CKY(I) =AKY2+(AKY1-AKY2)
     ,       *(YK2-Y2(I))/(YK2-YK1)
      IF (Y2(I) .GE. YK2 .AND. Y2(I) .LE. YK3)  CKY(I)=AKY2
      IF (Y2(I) .GT. YK3 .AND. Y2(I) .LT. YK4) CKY(I)=AKY2+(AKY3-AKY2)
     ,       *(Y2(I)-YK3)/(YK4-YK3)
      IF (Y2(I) .GE. YK4)  CKY(I)=AKY3
  170 CONTINUE
      DO 180 I=1,J2
  180 CKY(I)=(CKY(I)+CKY(I+1))*.5
      IF(METHOD.EQ.1) RETURN
      IF(TT.GE.TPLOT) RETURN
      DO 190 I=1,J1
      UA(I)=UA(I)-UBX
  190 WA(I)=WA(I)-WBZ
      RETURN
      END
vv
```

```
      SUBROUTINE INSOL
C
C     INTERPOLATE DATA ON Y1 TO Y2
C
      COMMON /COMPUT/EF(8,151),
     ,     E(8,151),Y1(151),Y2(151),DY(150),F(8),FH(8),WW(9),
     ,                   CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,AO,TY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AMO,DLDT,METHOD,TSTOP
C
C
      J1=ISIZE
      J2=ISIZE-1
      DO 90 K=1,6
      DO 90 J=1,J1
   90 EE(K,J)=0.
      PN2=.5*DY(1)
      DO 100 J=1,J1
      IF(PN2 .LE. Y1(J)) GO TO 110
  100 CONTINUE
  110 DO 120 K=1,6
  120 VAR(K)=E(K,J-1)+(E(K,J)-E(K,J-1))*
     ,                   (PN2-Y1(J-1))/(Y1(J)-Y1(J-1))
      IF(J .EQ. 2) GO TO 150
      JP2=J-2
      DO 140 K=1,6
      DO 130 J=1,JP2
  130 EE(K,1)=EE(K,1)+.5*(E(K,J)+E(K,J+1))*(Y1(J+1)-Y1(J))
  140 EE(K,1)=2.*(EE(K,1)+.5*(E(K,JP2+1)+VAR(K))*(PN2-Y1(JP2+1)))/DY(1)
      JP1=JP2+2
      GO TO 151
  150 DO 152 K=1,6
  152 FE(K,1)=     .5*(E(K,1)+VAR(K))
      JP1=J
  151 CONTINUE
      DO 310 I=2,J2
      PN1=PN2
      PN2=Y2(I)+.5*DY(I)
      DO 160 J=JP1,J1
      IF(PN2 .LE. Y1(J)) GO TO 170
  160 CONTINUE
  170 DO 180  K=1,6
  180 VAR(K+6)=E(K,J-1)+(E(K,J)-E(K,J-1))*(PN2-Y1(J-1))/(Y1(J)-Y1(J-1))
      IF(JP1 .EQ. J) GO TO 190
      IF (JP1+1 .EQ. J) GO TO 200
      JP2=J-2
      DO 210 K=1,6
  210 EE(K,I)=EE(K,I)+.5*(VAR(K)+E(K,JP1))*(Y1(JP1)-PN1)
      DO 220 K=1,6
      DO 230 J=JP1,JP2
  230 EE(K,I)=EE(K,I)+.5*(E(K,J)+E(K,J+1))*(Y1(J+1)-Y1(J))
  220 EE(K,I)=2.*(EE(K,I)+.5*(E(K,JP2+1)+VAR(6+K))*(PN2- Y1(JP2+1)))
     ,                /(DY(I)+DY(I-1))
      JP1=JP2+2
      GO TO 300
  190 DO 191 K=1,6
  191 EE(K,I)=2.*(EE(K,I)+.5*(VAR(K)+VAR(K+6))*(PN2-PN1))/
     ,          (DY(I)+DY(I-1))
      JP1=JP1
      GO TO 300
```

```
200 DO 201 K=1,6
201 EE(K,I)=2.*(EE(K,I)+.5*(VAR(K)+E(K,J-1))*(Y1(J-1)-PN1)
   ,    +.5*(E(K,J-1)+VAR(K+6))*(PN2-Y1(J-1)))/(DY(I)+DY(I-1))
    JP1=JP1+1
300 CONTINUE
    DO 310 K=1,6
310 VAR(K)=VAR(K+6)
    PN1=PN2
    JP2=J2
    IF(JP1 .EQ. J1) GO TO 320
    DO 330 K=1,6
330 EE(K,J1)=EE(K,J1)+.5*(VAR(K)+E(K,JP1))*(Y1(JP1)-PN1)
    DO 340 K=1,6
    DO 350 J=JP1,JP2
350 EE(K,J1)=EE(K,J1)+.5*(E(K,J)+E(K,J+1))*(Y1(J+1)-Y1(J))
340 EE(K,J1)=2.*EE(K,J1)/ DY(J1-1)
    GO TO 400
320 DO 360 K=1,6
360 EE(K,J1)=         (VAR(K)+E(K,J1))*(Y1(J1)-PN1) /DY(J2)
400 CONTINUE
    DO 500 I=1,J1
    Y1(I)=Y2(I)
    DO 500 K=1,6
    E(K,I)=EE(K,I)
500 CONTINUE
    RETURN
    END
vv
```

```
      SUBROUTINE ADD
C
C     ADD DATA ON Y2 TO DATA ON Y1
C
      COMMON            CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AB  (600),   DTT(600),   DL(600),
     ,                  CZ(600),SS(8,  600),
     ,             SVOL(600),CC(6,200),POSITN(600), T(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),XXXX (600),
     ,    BC(600),WS(4,2),
     ,        ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                  UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /COMPUT/EF(8,151),
     ,    EE(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                  CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     .  ,IJK,FBED,AMO,DLDT,METHOD,ISTOP
C
      J1=ISIZE
      J2=ISIZE-1
      DO 90 J=1,J2
   90 DY(J)=Y1(J+1)-Y1(J)
      DO 95 I=1,6
      DO 95 J=1,J1
   95 CC(I,J)=0.
      PN2=.5*DY(1)
      DO 100 J=1,J1
      IF(PN2 .LE. Y2(J)) GO TO 110
  100 CONTINUE
  110 DO 120 K=1,6
  120 VAR(K)=EE(K,J-1)+(EE(K,J)-EE(K,J-1))*
     ,                  (PN2-Y2(J-1))/(Y2(J)-Y2(J-1))
      IF(J .EQ. 2) GO TO 150
      JP2=J-2
      DO 140 K=1,6
      DO 130 J=1,JP2
  130 CC(K,1)=CC(K,1)+.5*(EE(K,J)+EE(K,J+1))*(Y2(J+1)-Y2(J))
  140 CC(K,1)=2.*(CC(K,1)+.5*(EE(K,JP2+1)+VAR(K))*(PN2-Y2(JP2+1)))/DY(1)
      JP1=JP2+2
      GO TO 151
  150 DO 152 K=1,6
  152 CC(K,1)=     .5*(EE(K,1)+VAR(K))
      JP1=J
  151 CONTINUE
      DO  10 I=2,J2
      PN1=PN2
      PN2=Y1(I)+.5*DY(I)
      DO 160 J=JP1,J1
      IF(PN2 .LE. Y2(J)) GO TO 170
  160 CONTINUE
  170 DO 180  K=1,6
  180 VAR(K+6)=EE(K,J-1)+(EE(K,J)-EE(K,J-1))*(PN2-Y2(J-1))
     ,      /(Y2(J)-Y2(J-1))
      IF(JP1 .EQ. J) GO TO 190
      IF (JP1+1 .EQ. J) GO TO 200
      JP2=J-2
      DO 210 K=1,6
  210 CC(K,I)=CC(K,I)+.5*(VAR(K)+EE(K,JP1))*(Y2(JP1)-PN1)
      DO 220 K=1,6
      DO 230 J=JP1,JP2
```

```
230 CC(K,I)=CC(K,I)+.5*(EE(K,J)+EE(K,J+1))*(Y2(J+1)-Y2(J))
220 CC(K,I)=2.*(CC(K,I)+.5*(EE(K,JP2+1)+VAR(6+K))*(PN2- Y2(JP2+1)))
   ,             /(DY(I)+DY(I-1))
    JP1=JP2+2
    GO TO 300
190 DO 191 K=1,6
191 CC(K,I)=2.*(CC(K,I)+.5*(VAR(K)+VAR(K+6))*(PN2-PN1))/
   ,        (DY(I)+DY(I-1))
    JP1=JP1
    GO TO 300
200 DO 201 K=1,6
201 CC(K,I)=2.*(CC(K,I)+.5*(VAR(K)+EE(K,J-1))*(Y2(J-1)-PN1)
   ,   +.5*(EE(K,J-1)+VAR(K+6))*(PN2-Y2(J-1)))/(DY(I)+DY(I-1))
    JP1=JP1+1
300 CONTINUE
    DO 310 K=1,6
310 VAR(K)=VAR(K+6)
    PN1=PN2
    JP2=J2
    IF(JP1 .EQ. J1) GO TO 320
    DO 330 K=1,6
330 CC(K,J1)=CC(K,J1)+.5*(VAR(K)+EE(K,JP1))*(Y2(JP1)-PN1)
    DO 340 K=1,6
    DO 350 J=JP1,JP2
350 CC(K,J1)=CC(K,J1)+.5*(EE(K,J)+EE(K,J+1))*(Y2(J+1)-Y2(J))
340 CC(K,J1)=2.*CC(K,J1)/ DY(J1-1)
    GO TO 400
320 DO 360 K=1,6
360 CC(K,J1)=         (VAR(K)+EE(K,J1))*(Y2(J1)-PN1) /DY(J2)
400 CONTINUE
    DO 450 I=1,6
    DO 450 J=1,J1
450 F(I,J)=F(I,J)+CC(I,J)
    RETURN
    END
vv
```

```
      SUBROUTINE SHIFT
      DIMENSION E1(151),X1(151),Z1(151),SIGX(151),SIGZ(151),SIGXZ(151)
      COMMON /C/X0,Z0
      COMMON             CX(600),CY(600),THETA2(600),U(600),
     , SZETA(600),CZETA(600),AA  (600),   DTT(600),   DL(600),
     ,                   CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600), T(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),CONC (600),
     ,    BC(600),WS(4,2),
     ,       ROAS(4),S(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                   UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                   CCMAX(151),VAR(151)
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,IJK,FBED,AMO,OLDT,METHOD,ISTOP
      J1=ISIZE
      J2=J1-1
      J=0
      DO 5 I=1,J1
      IF(E(1,I) .EQ. 0.)J=J+1
    5 CONTINUE
      IF(J .EQ. J1)6,7
    6 RETURN
    7 CONTINUE
      DO 1 I=1,J1
      IF(E(1,I) .EQ. 0.) GO TO 2
      E1(I)=1./E(1,I)
      X1(I)=E(2,I)*E1(I)
      Z1(I)=E(3,I)*E1(I)
      SIGX(I)=E(4,I)*E1(I)-X1(I)**2
      SIGZ(I)=E(5,I)*E1(I)-Z1(I)**2
      SIGXZ(I)=E(6,I)*E1(I)-X1(I)*Z1(I)
      GO TO 1
    2 X1(I)=0.
      Z1(I)=0.
      SIGX(I)=0.
      SIGZ(I)=0.
      SIGXZ(I)=0.
    1 CONTINUE
      IF(F(1) .EQ. 0.)GO TO 9
      F1=1./F(1)
      XX1=F(2)  *F1
      ZZ1=F(3)  *F1
      SIGXX=F(4)*F1-XX1**2
      SIGZZ=F(5)*F1-ZZ1**2
      SIGXXZZ=F(6)*F1-XX1*ZZ1
      GO TO 8
    9 XX1=0.
      ZZ1=0.
      SIGXX=0.
      SIGZZ=0.
      SIGXXZZ=0.
    8 CONTINUE
      AM0=0.
      AM1=0.
      AM2=0.
      DO 3 I=1,J2
      AM0=AM0+(E(1,I)+E(1,I+1))*DY(I)*.5
      AM1=AM1+(E(1,I)*X1(I)+E(1,I+1)*X1(I+1))*DY(I)*.5
    3 AM2=AM2+(E(1,I)*Z1(I)+E(1,I+1)*Z1(I+1))*DY(I)*.5
      X01=AM1/AM0
      Z01=AM2/AM0
      DO 4 I=1,J1
      E(2,I)=E(1,I)*(X1(I)-X01)
      E(3,I)=E(1,I)*(Z1(I)-Z01)
      E(4,I)=ABS(E(1,I)*((X1(I)-X01)**2+SIGX(I)))
      E(5,I)=ABS(E(1,I)*((Z1(I)-Z01)**2+SIGZ(I)))
      E(6,I)=E(1,I)*((X1(I)-X01)*(Z1(I)-Z01)+SIGXZ(I))
    4 CONTINUE
      F(2)=F(1)*(XX1-X01)
      F(3)=F(1)*(ZZ1-Z01)
      F(4)=ABS(F(1)*((XX1-X01)**2+SIGXX))
      F(5)=ABS(F(1)*((ZZ1-Z01)**2+SIGZZ))
      F(6)=F(1)*((XX1-X01)*(ZZ1-Z01)+SIGXZZ)
      X0=X0+X01
      Z0=Z0+Z01
      DO 11 I=1,ISTEP
      CX(I)=CX(I)-X01
   11 CZ(I)=CZ(I)-Z01
      RETURN
      END
vv
```

```
      FUNCTION DISPC(ALAMDA,J)
      COMMON /COMPUT/FF(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
C
C     FUNCTION FOR COMPUTING THE DISPERSION COEFFICIENT KX,KZ
C
      IF(FE(1,J) .LE. 1.00E-15) GO TO 1
      DISPC =ALAMDA*(ABS(ABS(FF(4,J)*FF(1,J)-FF(2,J)**2)*
     ,           ABS(EE(5,J)*EE(1,J)-FF(3,J)**2)
     ,              -(EE(6,J)*EE(1,J)-EE(2,J)*FF(3,J))**2)/FF(1,J)**4)
     ,                   **0.3333333
      RETURN
    1 DISPC=0.
      RETURN
      END
vv
```

```
      FUNCTION DISPCC(ALAMDA,J)
      COMMON /COMPUT/EE(8,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
      IF( E(1,J) ,LE, 1,00E-15) GO TO 1
      DISPCC=ALAMDA*(ABS(ABS( E(4,J)* E(1,J)- E(2,J)**2)*
     ,           ABS( E(5,J)* E(1,J)- E(3,J)**2)
     ,               -( E(6,J)* E(1,J)- E(2,J)* E(3,J))**2)/ E(1,J)**4)
     ,                     **0,3333333
      RETURN
    1 DISPCC=0,
      RETURN
      END
vv
```

```
      FUNCTION DISPW(ALAMDA)
      COMMON /COMPUT/FE(8,151),
     ,    F(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                 CCMAX(151),VAR(151)
C
C     FUNCTION FOR COMPUTING THE DISPERSION COEFFICIENT KX,KZ FOR SOLID
C     ON SURFACE
C
      IF(VAR(1) .LE. 1.00E-15) GO TO 1
      DISPW =ALAMDA*(ABS(ABS(VAR(4)* VAR(1)-VAR(2)**2)*
     ,            ABS(VAR(5)*VAR(1)-VAR(3)**2)
     ,  -(VAR(6)*VAR(1)-VAR(2)*VAR(3))**2)/VAR(1)**4)**0.3333333
      RETURN
    1 DISPW=0.
      RETURN
      END
```

```
  FUNCTION DISPWW(ALAMDA)
  COMMON /COMPUT/FE(8,151),
 ,     E(8,151),Y1(151),Y2(151),DV(150),F(8),FW(8),WW(9),
 ,                 CCMAX(151),VAR(151)
  IF(  F(1) .LE. 1.00E-15) GO TO 1
  DISPWW=ALAMDA*(ABS(ABS(  F(4)*   F(1)-  F(2)**2)*
 ,             ABS(  F(5)*  F(1)-  F(3)**2)
 ,  -(  F(6)*  F(1)-  F(2)*  F(3))**2)/  F(1)**4)**0.3333333
  RETURN
1 DISPWW=0.
  RETURN
  END
```

```
      SUBROUTINE OUTPT
C
C     OUTPUT SUBROUTINE
C
      DIMENSION SC(152,4),SG(152,4),SX(152,4),SZ(152,4),SSX(152,4),SSZ(1
     *52,4),TP(200),FKC(200),FKX(200),FKZ(200),FKSX(200),FKSZ(200),
     *FKSXZ(200) ,SXZ(152,4),SIZ(152,4),FSIZ(200)
      COMMON/CNOMOR/NOMOR,TPLOT
      COMMON /C/X0,Z0
      COMMON /COMPUT/XX(151),ZZ(151),SIGMAX(151),SIGMAZ(151),
     ,      SIGMAXZ(151),DUMMY(3,151),
     ,    E(8,151),Y1(151),Y2(151),DY(150),F(8),FW(8),WW(9),
     ,                CCMAX(151),VAR(151)
      COMMON /TORS/ DT,DT1,DT2,CDT,NGRID,NGRID1,NGRID2,NGRID3,NCD
      COMMON /CONST/G,PAI,ALPHA0,ALPHA,ALPHAC,ALPHA1,ALPHA2,
     ,      ALPHA3,ALPHA4,GAMA,CDRAG,CFRIC,BETA,CM,CD,CD1,CD2,FRICTN,F1
     ,  ,ALFA1,ALFA2,GAMA1,GAMA2,ALAMDA,CD3,CD4
      COMMON          CX(600),CY(600),AA     (600),U(600),
     ,     V(600),     W(600),VORT(600),DENDIF(600),ENTRCO(600),
     ,                CZ(600),SS(8,  600),
     ,     SVOL(600),XC(600),ZC(600),POSITN(600),CB(600),THICK(600),
     ,    SUA(200),SWA(200),SCKY(200),DUMY2(600),
     ,    BC(600),WS(4,2),
     ,        ROAS(4),T(600),K,L,IPLUNG,NUTRL,UB,SAI,TIME,ISTEP,  VF,
     ,                UBX,WBZ,ROAF,CMAX(9),YY
      COMMON /TRASFER/ KK,JJ,TT,ISIZE,NOTE,A0,IY,NOTRN,INDEX,IBED,ILEAVE
     ,  ,TJK,FBED,AM0,DLDT,METHOD,TSTOP
      COMMON/KOH1/ INDE ,TRIGER(4),CMAXMAX,TOTMAX,KKK
      COMMON/KOH2/ IFINISH
      COMMON/GRAPH/TIM(4)
      COMMON/GP/IGCN,IGCL,IGLT,IPCN,IPCL,IPLT,NSCALE
      NOMOR=0
      IF(KK .LE. L)IP=1
      IF(KK .GT. L .AND. KK .LE. 2*L)IP=2
      IF(KK .GT. 2*L .AND. KK .LE. 3*L)IP=3
      IF(KK .GT. 3*L .AND. KK .LE. 4*L)IP=4
      J1=ISIZE
      J2=J1-1
      JS=J1/50
      ELIMIT=1.00E-15
      DO 100 I=1,J1
      IF(E(1,I) .LE.   ELIMIT  )          101,102
  101 XX(I)=0.
      ZZ(I)=0.
      SIGMAX(I)=0.
      SIGMAZ(I)=0.
      SIGMAXZ(I)=0.
      CCMAX(I)=0.
      GO TO 100
  102 E1I=1./E(1,I)
      XX(I)=E(2,I)*E1I
      ZZ(I)=E(3,I)*E1I
      SIGMAX(I)=ABS(E(4,I)*E1I   -XX(I)**2  )
      SIGMAZ(I)=ABS(E(5,I)*E1I   -ZZ(I)**2)
      SIGMAXZ(I)=         E(6,I)*E1I   -XX(I)*ZZ(I)
      XX(I)=XX(I)+X0
      ZZ(I)=ZZ(I)+Z0
      VAR(I)=SQRT(ABS(SIGMAX(I)   *SIGMAZ(I)-SIGMAXZ(I)**2))
      CCMAX(I)=0.5* E(1,I)/(PAI*VAR(I))
  100 CONTINUE
```

```
      IF(WW(KK)) 110,120 ,110
  110 IF (F(1)   .LE.  ELIMIT   ) 111,112
  111 X=0.
      Z=0.
      SIGX=0.
      SIGZ=0.
      SIGXZ=0.
      GO TO 120
  112 F1=1./F(1)
      X=F(2)*F1
      Z=F(3)*F1
      SIGX=ABS(F(4)*F1  -X**2)
      SIGZ=ABS(F(5)*F1  -Z**2 )
      SIGXZ=F(6)*F1  -X*Z
      X=X+X0
      Z=Z+Z0
  120 AM0=0.
      AM1=0.
      DO 130 I=1,J2
      AM0=AM0+(F(1,I)+F(1,I+1))*DY(I)*.5
      AM1=AM1+(Y1(I)*F(1,I)+Y1(I+1)*F(1,I+1))*DY(I)*.5
  130 CONTINUE
      IF (IFINISH .EQ. 1)GO TO 7007
      IF(IPLT.EQ.0) GO TO 8001
      COOMX=0.
      DO 7002 I=1,J1
      IF(F(1,I).GT.COOMX) COOMX=F(1,I)
 7002 CONTINUE
      IF(AM0.EQ.0.) GO TO 7001
      IF(TT.LE.TPLOT) GO TO 7001
      IF(ABS((COOMX-OLDMX)/OLDMX).LT.0.1.AND.(GAMA1+GAMA2).LE.1.E-6)
     * GO TO 8001
 7001 OLDMX=COOMX
 7007 CONTINUE
      WRITE(6,1)
    1 FORMAT(1H1      )
      IF(AM0 .EQ. 0.)131,132
  132 YBAR=AM1/AM0
      GO TO 133
  131 YBAR=0.
  133 CONTINUE
      IF(WW(KK)) 140,150,160
  140 WRITE(6,2)TT,YBAR,ROAS(IP),WW(KK),AM0
    2 FORMAT(10X,4HTIME,F12.4,4HSEC.,2X, 6HMEAN Y,       F9.3,3HFT., 2X,
     ,      13HSOLID DENSITY,F5.3,5HGM/CC,2X,
     ,             9HFALL VEL.,F12.4,6HFT/SEC,4H TSS, F12.4,5HCUFT.)
      WRITE(6,3)
    3 FORMAT(/25X,20HSOLID ON THE SURFACE/)
      WRITE(6,4)
    4 FORMAT(35X,1HX,9X,1HZ,7X,6HSIGMAX,6X,6HSIGMAZ,6X,7HSIGMAXZ,5X,
     ,        14HFLOATING SOLID)
      WRITE(6,20)X,Z,SIGX,SIGZ,SIGXZ,F(1)
   20 FORMAT(28X,6E12.4/)
      IF(AM0 .EQ. 0.)GO TO 200
      WRITE(6,5)
    5 FORMAT(/25X,19HSOLID IN SUSPENSION/)
      WRITE(6,10)
   10 FORMAT(25X,1HY,9X,1HX,9X,1HZ,7X,6HSIGMAX,6X,6HSIGMAZ,6X,7HSIGMAXZ,
     ,        4X,5HCONC.,7X,3HC00)
      DO 141 I=1,J1,J8
  141 WRITE(6,21)Y1(I),XX(I),ZZ(I),SIGMAX(I),SIGMAZ(I),SIGMAXZ(I),
     ,             CCMAX(I),E(1,I)
   21 FORMAT(20X,F6.1,7E12.4)
      GO TO 200
  150 WRITE(6,7)TT,YBAR,AMO
    7 FORMAT(25X,4HTIME,E12.4,4HSEC.,2X, 6HMEAN Y,       F9.3,3HFT.,
     ,        12H TOTAL WASTE,E12.4,5HCQFT.)
      WRITE(6,8)
    8 FORMAT(/25X,28HFLUID PART OF WASTE MATERIAL/)
      WRITE(6,6)
    6 FORMAT(25X,1HY,9X,1HX,9X,1HZ,7X,6HSIGMAX,6X,6HSIGMAZ,6X,7HSIGMAXZ,
     ,        4X,10H  CONC.    ,5X,3HC00)
      DO 151 I=1,J1,JS
  151 WRITE(6,21)Y1(I),XX(I),ZZ(I),SIGMAX(I),SIGMAZ(I),SIGMAXZ(I),
     ,             CCMAX(I),E(1,I)
      GO TO 200
  160 WRITE(6,2)TT,YBAR,ROAS(IP),WW(KK),AMO
      IF(AMO .EQ. 0.)GO TO 162
      WRITE(6,5)
      WRITE(6,10)
      DO 161 I=1,J1,JS
  161 WRITE(6,21)Y1(I),XX(I),ZZ(I),SIGMAX(I),SIGMAZ(I),SIGMAXZ(I),
     ,             CCMAX(I),E(1,I)
  162 WRITE(6,9)
    9 FORMAT(/25X,16HSOLID ON THE BED/)
      WRITE(6,11)
   11 FORMAT(35X,1HX,9X,1HZ,7X,6HSIGMAX,6X,6HSIGMAZ,6X,7HSIGMAXZ,5X,
     ,        15HDEPOSITED SOLID)
      WRITE(6,20)X,Z,SIGX,SIGZ,SIGXZ,F(1)
  200 CONTINUE
 8001 IF(IGLT.EQ.0) GO TO 8002
      IF(WW(KK)) 8000,800,8000
 8000 IF(KKK.EQ.199) GO TO 800
      KKK=KKK+1
      TP(KKK)=TT
      FKC(KKK)=F(1)
      FKX(KKK)=X
      FKZ(KKK)=Z
      FKSX(KKK)=SIGX
      FKSZ(KKK)=SIGZ
      FKSXZ(KKK)=SIGXZ
      FSIZ(KKK)=-1.
      TEMPOR=               SIGX*SIGZ-SIGXZ**2
      IF(TEMPOR.GE.0.) FSIZ(KKK)=SQRT(SQRT(TEMPOR))*2.
  800 CONTINUE
      IF(TT.LT.TPLOT) GO TO 8002
      COOMAX=0.
      DO 8003 I=1,J1
      IF(E(1,I).GT.COOMAX) COOMAX=E(1,I)
 8003 CONTINUE
      IF(AMO.EQ.0.) GO TO 8004
      IF(COOMAX.GT.CMAXMAX) CMAXMAX=COOMAX
      IF(AMO.GT.TOTMAX) TOTMAX=AMO
      COOR=COOMAX/CMAXMAX
      TOTR=AMO/TOTMAX
      IF(COOR.GT.TRIGER(INDE ).AND.TOTR.GT.TRIGER(INDE )) GO TO 8004
      IF(TIM(4).GT.0.5) GO TO 8004
      TIM(INDE)=TT
      DO 8005 I=1,J1
      SG(I,INDE )=Y1(I)
      SC(I,INDE )=F(1,I)
      SX(I,INDE )=XX(I)
      SZ(I,INDE )=ZZ(I)
      SSX(I,INDE )=SIGMAX(I)
      SSZ(I,INDE )=SIGMAZ(I)
      SXZ(I,INDE )=SIGMAXZ(I)
      SIZ(I,INDE)=-1.
      TEMPO=                     SIGMAX(I)*SIGMAZ(I)-SIGMAXZ(I)**2
      IF(TEMPO .GE.0.) SIZ(I,INDE)=SQRT(SQRT(TEMPO))*2.
 8005 CONTINUE
      IF(INDE .EQ.4) GO TO 8004
      INDE =INDE +1
 8004 CONTINUE
      IF(TIM(4).GT.0.5) NOMOR=1
      IF(IFINISH.EQ.0) GO TO 8002
      IF(WW(KK).EQ.0.) GO TO 8011
      KKK=KKK+1
      TP(KKK)=2.*TP(KKK-1)-TP(KKK-2)
      FKC(KKK)=0.
      FKX(KKK)=0.
      FKZ(KKK)=0.
      FKSX(KKK)=0.
      FKSZ(KKK)=0.
      FKSXZ(KKK)=0.
      FSIZ(KKK)=0.
 8011 IF(INDE .EQ.1) GO TO 8012
      JJJ=J1+1
      DO 8007 I=1,INDE
      SG (JJJ ,I     )=2.*Y1(J1)-Y1(J1-1)
      SC (JJJ ,I     )=0.
      SX (JJJ ,I     )=0.
      SZ (JJJ ,I     )=0.
      SSX(JJJ ,I     )=0.
      SSZ(JJJ ,I     )=0.
      SXZ(JJJ ,I     )=0.
      SIZ(JJJ ,I     )=0.
 8007 CONTINUE
      INDE=INDE-1
      IF(TIM(4).GT..5) INDE=4
      CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SC(1,1),SC(1,2),SC(1,3),
     *SC(1,4),JJJ,5,NSCALE,INDE )
 8012 IF(WW(KK).EQ.0.) GO TO 8010
      CALL DRAW(TP,TP,TP,TP,FKC,FKX,FKZ,FSIZ,KKK,12,NSCALE,4)
      CALL DRAW(TP,TP,TP,TP,FKSX,FKSZ,FKSXZ,FKC,KKK,13,NSCALE,3)
 8010 CONTINUE
      IF(INDE.EQ.1) GO TO 8006
      CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SIZ(1,1),SIZ(1,2),SIZ(1,
     *3),SIZ(1,4),JJJ,17,NSCALE,INDE)
       IF(IGLT.EQ.1) GO TO 8006
       CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SX(1,1),SX(1,2),SX(1,3),
     *SX(1,4),JJJ,8,NSCALE,INDE )
       CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SZ(1,1),SZ(1,2),SZ(1,3),
     *SZ(1,4),JJJ,9,NSCALE,INDE )
       IF(IGLT.EQ.2) GO TO 8006
       CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SSX(1,1),SSX(1,2),SSX(1,
     *3),SSX(1,4),JJJ,6,NSCALE,INDE)
       CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SSZ(1,1),SSZ(1,2),SSZ(1,
     *3),SSZ(1,4),JJJ,7,NSCALE,INDE)
       CALL DRAW(SG(1,1),SG(1,2),SG(1,3),SG(1,4),SXZ(1,1),SXZ(1,2),SXZ(1,
     *3),SXZ(1,4),JJJ,14,NSCALE,INDE)
 8006 CONTINUE
      INDE =1
      KKK=0
      CMAXMAX=0.
      TOTMAX=0.
      TIM(4)=0.
 8002 CONTINUE
      IFINISH=0
      RETURN
      END
VV
```

```
      SUBROUTINE DRAW (X1,X2,X3,X4,Y1,Y2,Y3,Y4,N,IG,NSCALE,NCURV)
      DIMENSION X1(1),X2(1),X3(1),X4(1),Y1(1),Y2(1),Y3(1),Y4(1),X(800),
     *Y(800),YY(800),SYM(4),SIM(16),P(2400)
      COMMON/SIZE/NX,NY
      COMMON/GRAPH/TIM(4)
      DATA SIM/1HY,1HB,1HC,1HS,1HA,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1HT,
     * 1HX,1HZ/
      IF(NCURV.LT.1) RETURN
      IF(NSCALE.GT.60) NSCALE=60
      IN = N/NSCALE
      IF(IN.LT.1) IN=1
      J=0
      DO 1 I=1,N,IN
      J=J+1
      X(J)=X1(I)
    1 Y(J)=Y1(I)
      J=J+1
      X(J)=X1(N)
      Y(J)=Y1(N)
      NN=J
      IF(NCURV.EQ.1) GO TO 5
      DO 2 I=1,N,IN
      J=J+1
      X(J)=X2(I)
    2 Y(J)=Y2(I)
      J=J+1
      X(J)=X2(N)
      Y(J)=Y2(N)
      IF(NCURV.EQ.2) GO TO 5
      DO 3 I=1,N,IN
      J = J+1
      X(J)=X3(I)
    3 Y(J)=Y3(I)
      J=J+1
      X(J)=X3(N)
      Y(J)=Y3(N)
      IF(NCURV.EQ.3) GO TO 5
      DO 4 I=1,N,IN
      J=J+1
      X(J)=X4(I)
    4 Y(J)=Y4(I)
      J=J+1
      X(J)=X4(N)
      Y(J)=Y4(N)
    5 CONTINUE
      GO TO (10,20,10,20,30,30,30,30,30,50,60,70,80,90,2000,1000,3000)
     *   ,IG
   10 DO 11 I=1,4
   11 SYM(I)=SIM(I)
      SYM(4)=SIM(16)
      IF(IG.EQ.1) SYM(3)=SIM(15)
      CALL NORM(Y,YY,NN,1.,0.,AMXY,AMNY)
      NN1=NN+1
      CALL NORM(Y(NN1),YY(NN1),NN,0.4,0.,AMXB,AMNB)
      NN1=NN1+NN
      IF(IG.EQ.3) CALL NORM(Y(NN1),YY(NN1),NN,1. ,0.,AMXC,AMNC)
      IF(IG.EQ.1) CALL NORM(Y(NN1),YY(NN1),NN,0.6,0.,AMXC,AMNC)
      NN1=NN1+NN
      CALL NORM (Y(NN1),YY(NN1),NN,0.8,0.,AMXS,AMNS)
      IF(IG.EQ.1) WRITE(6,110) X(1),X(NN),AMXY,AMXB,AMXC,AMXS
     * ,AMNY,AMNB,AMNC,AMNS
      IF(IG.EQ.3) WRITE(6,130) X(1),X(NN),AMXY,AMXB,AMXC,AMXS
     * ,AMNY,AMNB,AMNC,AMNS
      CALL SPLOT(YY,X,P,J,NY,NX,1,NN,1,4,SYM)
  110 FORMAT(1H1,/////,21X,38HDATA FOR GRAPH IMMEDIATELY FOLLOWING    ,
     *///,10X,46HINDEPENDENT VARIABLE IS    TIME     OVER RANGE    ,2X,
     1 2G12.5,///,30X,19HDEPENDENT VARIABLES    ,//,10X,6HSYMBOL,13X,
     2 1HY,14X,1HB,13X,1HX,13X,1HZ,/,10X,11HMAX PLOTTED ,3X,G12.5,
     3 3(2X,G12.5),/,10X,11HMIN PLOTTED ,3X,G12.5,3(2X,G12.5),/,10X,
     *                       7HREMARKS,8X,11HVERT. DIST. ,4X,9H RADIUS   ,4X,
     4 11H HOR. DIST.  ,3X,11H HOR. DIST. )
  130 FORMAT(1H1,/////,21X,38HDATA FOR GRAPH IMMEDIATELY FOLLOWING    ,
     *///,10X,46HINDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE    ,2X,
     1 2G12.5,///,30X,19HDEPENDENT VARIABLES    ,//,10X,6HSYMBOL,13X,
     2 1HY,14X,1HB,13X,1HC,13X,1HZ,/,10X,11HMAX PLOTTED ,3X,G12.5,
     3 3(2X,G12.5),/,10X,11HMIN PLOTTED ,3X,G12.5,3(2X,G12.5),/,10X,
     *                       7HREMARKS,8X,11HVERT. DIST. ,4X,9H RADIUS   ,4X,
     4 11HFLUID CONC.  ,3X,11H HOR. DIST. )
      RETURN
   20 SYM(1)=SIM(5)
      SYM(2)=SIM(2)
      SYM(3)=SIM(15)
      IF(IG.EQ.4) SYM(3)=SIM(16)
      SYM(4)=SIM(1)
      CALL NORM (Y,YY,NN,1.,0.,AMXA,AMNA)
      NN1=NN+1
      CALL NORM (Y(NN1),YY(NN1),NN,.5,0.,AMXB,AMNB)
      NN1=NN1+NN
      CALL NORM (Y(NN1),YY(NN1),NN,.8,0.,AMXC,AMNC)
      NN1=NN1+NN
      CALL NORM (Y(NN1),YY(NN1),NN,1. .0.,AMXS,AMNS)
      IF(IG.EQ.2) WRITE (6,120) X(1),X(NN),AMXA,AMXB,AMXC,AMXS
     * ,AMNA,AMNB,AMNC,AMNS
      IF(IG.EQ.4) WRITE(6,140)  X(1),X(NN),AMXA,AMXB,AMXC,AMXS
     * ,AMNA,AMNB,AMNC,AMNS
      CALL SPLOT(YY,X,P,J,NY,NX,1,NN,1,4,SYM)
  120 FORMAT(1H1,/////,21X,38HDATA FOR GRAPH IMMEDIATELY FOLLOWING    ,
     *///,10X,46HINDEPENDENT VARIABLE IS    TIME     OVER RANGE    ,2X,
     1 2G12.5,///,30X,19HDEPENDENT VARIABLES    ,//,10X,6HSYMBOL,13X,
     2 1HA,14X,1HB,13X,1HX,13X,1HY,/,10X,11HMAX PLOTTED ,3X,G12.5,
     3 3(2X,G12.5),/,10X,11HMIN PLOTTED ,3X,G12.5,3(2X,G12.5),/,10X,
     *                       7HREMARKS,8X,11HVERT. SIZE. ,4X,9HHOR. SIZE,4X,
     4 11H HOR. DIST.  ,3X,11HVERT. DIST. )
  140 FORMAT(1H1,/////,21X,38HDATA FOR GRAPH IMMEDIATELY FOLLOWING    ,
     *///,10X,46HINDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE    ,2X,
     1 2G12.5,///,30X,19HDEPENDENT VARIABLES    ,//,10X,6HSYMBOL,13X,
     2 1HA,14X,1HB,13X,1HZ,13X,1HY,/,10X,11HMAX PLOTTED ,3X,G12.5,
     3 3(2X,G12.5),/,10X,11HMIN PLOTTED ,3X,G12.5,3(2X,G12.5),/,10X,
     *                       7HREMARKS,8X,11HVERT. SIZE. ,4X,9HHOR. SIZE,4X,
     4 11H HOR. DIST.  ,3X,11HVERT. DIST. )
      RETURN
   30 DO 31 I=1,4
   31 SYM(I)=SIM(I+5)
      CALL RANGE(Y,J,AMX,AMN,JMX,JMN)
      IF(AMX.EQ.0..AND.AMN.EQ.0.) RETURN
      IF(NCURV.EQ.4) GO TO 34
      NCURV1=NCURV+1
      DO 33 I=NCURV1,4
   33 TIM (I)=-1.
   34 CONTINUE
```

```
      IGG=IG-4
      GO TO (41,42,43,44,45) IGG
   41 WRITE (6,141) (TIM (I),I=1,4),X(1),X(NN),AMN,AMX
      GO TO 32
   42 WRITE (6,142) (TIM (I),I=1,4),X(1),X(NN),AMN,AMX
      GO TO 32
   43 WRITE (6,143) (TIM (I),I=1,4),X(1),X(NN),AMN,AMX
      GO TO 32
   44 WRITE (6,144) (TIM (I),I=1,4),X(1),X(NN),AMN,AMX
      GO TO 32
   45 WRITE (6,145) (TIM (I),I=1,4),X(1),X(NN),AMN,AMX
   32 CALL SPLOT( Y,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
  141 FORMAT(1H1,////////////39X,31HGRAPH OF   COD   VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF   COD   PLOTTED  ,1X,2G20.8)
  142 FORMAT(1H1,////////////39X,31HGRAPH OF SIGMA-X VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF SIGMA-X PLOTTED  ,1X,2G20.8)
  143 FORMAT(1H1,////////////39X,31HGRAPH OF SIGMA-Z VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF SIGMA-Z PLOTTED  ,1X,2G20.8)
  144 FORMAT(1H1,////////////39X,31HGRAPH OF    XO   VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF    XO   PLOTTED  ,1X,2G20.8)
  145 FORMAT(1H1,////////////39X,31HGRAPH OF    ZO   VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF    ZO   PLOTTED  ,1X,2G20.8)
      RETURN
   50 DO 51 I=1,4
   51 SYM(I)=SIM(I+5)
   52 CALL RANGE(Y,J,AMXS,AMNS,JMX,JMN)
      WRITE(6,500) X(1),X(NN),AMNS,AMXS
      CALL SPLOT( Y,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
  500 FORMAT(1H1,/////,2X,31HGRAPH OF WASTE  CONCENTRATIONS  ,//,
     * 2X,12HRANGE OF X  ,20X,2G20.8,/ ,2X,32HRANGE OF CONCENTRATIONS PL
     1OTTED   ,  2G20.8, 8(/))
      RETURN
   60 DO 61 I=1,4
   61 SYM(I)=SIM(I+9)
      GO TO 52
   70 CONTINUE
      SYM(1)=SIM(14)
      SYM(2)=SIM(15)
      SYM(3)=SIM(16)
      SYM(4)=SIM(4)
      CALL NORM(Y,YY,NN,1.,0.,AMXT,AMNT)
      NN1=NN+1
      CALL NORM(Y(NN1),YY(NN1),NN,0.75,0.,AMXX,AMNX)
      NN1=NN1+NN
      CALL NORM(Y(NN1),YY(NN1),NN,0.5 ,0.,AMXZ,AMNZ)
      NN1=NN1+NN
      CALL NORM(Y(NN1),YY(NN1),NN,0.6 ,0.,AMXS,AMNS)
      WRITE(6,701) X(1),X(NN),AMXT,AMXX,AMXZ,AMXS,AMNT,AMNX,AMNZ,AMNS
      CALL SPLOT(YY,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
  701 FORMAT(1H1,/////,2X, 74HPLOT OF TOT BDRY MAT (T) CENTROID LOCATION
     *S (X,Z) AND SIZE (S) VS TIME      ,// ,2X, 12HTIME RANGE   ,4X,
     1 2G20.8,/ ,2X,16HMAXIMUM T,X,Z,S  ,4G20.8,/,2X,16HMINIMUM T,X,Z,S
     3  ,  4G20.8,7(/))
      RETURN
   80 CONTINUE
```

```
      SYM(1)=SIM(15)
      SYM(2)=SIM(16)
      SYM(3)=SIM(4)
      CALL NORM(Y,YY,NN,1.,0.,AMXT,AMNT)
      NN1=NN+1
      CALL NORM(Y(NN1),YY(NN1),NN,0.5 ,0.,AMXX,AMNX)
      NN1=NN1+NN
      CALL NORM(Y(NN1),YY(NN1),NN,0.75,0.,AMXZ,AMNZ)
      WRITE(6,801) X(1),X(NN),AMXT,AMXX,AMXZ,AMNT,AMNX,AMNZ
      CALL SPLOT(YY,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
  801 FORMAT(1H1,/////,2X,70HPLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z
     *) AND SIGMAXZ (S) VS. TIME   ,// ,2X, 12HTIME RANGE= ,4X,2G20.8,/
     1 ,2X,16HMAXIMUM X,Z,S    ,3G20.8,/,2X,16HMINIMUM X,Z,S    ,
     2 3G20.8,7(/))
      RETURN
   90 DO 91 I=1,4
   91 SYM(I)=SIM(I+5)
      CALL RANGE(Y,J,AMX,AMN,JMX,JMN)
      IF(AMX.EQ.0..AND.AMN.EQ.0.) RETURN
      IF(NCURV.EQ.4) GO TO 94
      NCURV1=NCURV+1
      DO 93 I=NCURV1,4
   93 TIM (I)=-1.
   94 CONTINUE
      WRITE (6,900) (TIM (I),I=1,4    ),X(1),X(NN),AMN,AMX
      CALL SPLOT( Y,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
  900 FORMAT(1H1,///////////39X,31HGRAPH OF SIGMAXZ VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF SIGMAXZ PLOTTED  ,1X,2G20.8)
      RETURN
 1000 DO 1001 I=2,4
 1001 SYM(I)=SIM(I+4)
      SYM(1)=SIM(3)
      GO TO 52
 2000 SYM(1)=SIM(15)
      CALL RANGE(Y,J,AMX,AMN,JMX,JMN)
      IF(AMN.EQ.0..AND.AMX.EQ.0.) RETURN
      WRITE(6,2001) X(1),X(NN),AMN,AMX
 2001 FORMAT(1H1,11(/),20X,15HGRAPH OF X VS Z,//,2X,10HRANGE OF X,
     *2G20.8,/,2X,10HRANGE OF Z,2G20.8)
      CALL SPLOT(Y,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
      RETURN
 3000 DO 3001 I=1,4
 3001 SYM(I)=SIM(I+5)
      CALL RANGE(Y,J,AMX,AMN,JMX,JMN)
      IF(NCURV.EQ.4) GO TO 3094
      NCURV1=NCURV+1
      DO 3093 I=NCURV1,4
 3093 TIM (I)=-1.
 3094 CONTINUE
      WRITE (6,3300)(TIM (I),I=1,4    ),X(1),X(NN),AMN,AMX
      CALL SPLOT( Y,X,P,J,NY,NX,1,NN,1,NCURV,SYM)
 3300 FORMAT(1H1,///////////39X,31HGRAPH OF   SIZE  VS Y AT TIMES ,/,9X,
     *4G20.8,//,20X,25HRANGE OF    Y    PLOTTED  ,1X,2G20.8,/,20X,25HRAN
     1GE OF   SIZE  PLOTTED  ,1X,2G20.8)
      RETURN
      END
vv
```

```
      SUBROUTINE SPLOT(B,A,P,N,L,M,JSTR,NREP,NUMB,NSYM,SYM)
      DIMENSION A(1),B(1),SYM(1) ,P(1),Q(20),H(10)                      SPLOT
      DATA Q/20*5H----I/
      DATA STR/1H=/
      DATA END/1H//
      DATA BL6/6H      /
      DATA EYE/1HI/
      DATA BLNK/1H /
      IF(NREP.LT.1) NREP=1
      LOLD=L
      L6=L/6
      L=6*L6
      LQ=L6-1
      NNUM=N*NUMB
      NUM1=NUMB-1
      ML=(M+1)*(L6+1)
      JZA=0
      ZRO=0.
      DO 1916 J=1,ML
 1916 P(J)=BL6
      FM=M-1
      FL=L -1
      AMX=A(1)
      AMN=A(1)
      BMX=B(1)
      BMN=B(1)
      DO 100 J=2,N
      IF(A(J).GT.AMX) AMX=A(J)
  100 IF(A(J).LT.AMN) AMN=A(J)
      DO 105 J=2,NNUM
      IF(B(J).GT.BMX) BMX=B(J)
  105 IF(B(J).LT.BMN) BMN=B(J)
      DA=(AMX-AMN)/FM
      DB=(BMX-BMN)/FL
      WRITE(6,2000) AMX,AMN,DA
 2000 FORMAT(/////,1X,26HMAX,MIN,INC, OF IND.VAR.   ,/,1X,6G20.8)
      WRITE(6,2001) BMX,BMN,DB
 2001 FORMAT(//,1X,26HMAX,MIN,INC, OF DEP. VAR.   ,/,1X,6G20.8)
      WRITE(6,2002)
 2002 FORMAT(36(/))
      TESTA=AMX*AMN
      TESTB=BMX*BMN
      IF(TESTA) 1971,1972,1972
 1971 JZA=-AMN/DA
 1972 IF(TESTB) 1973,1975,1975
 1973 IB=-BMN/DB
      LIA=-L6
      DO 1974 J=1,M
      LIA=LIA+L6
 1974 CALL PFIX(P,IB,LIA,EYE)
 1975 CONTINUE
      L10=LOLD/20+1
      DB20=20.*DB
      HBM=BMN-DB20
      DO 2020 J=1,L10
 2020 H(J)=HBM+J*DB20
      WRITE(6,2021) (H(J),J=1,L10)
 2021 FORMAT(  3X,6G20.5)
      WRITE(6,1200) (Q(J),J=1,20)
 1200 FORMAT(16X,20A5)
```

```
      JPQ=1
      NPQ=N
      DO 200 J=JPQ,NPQ
      IA=(A(J)-AMN)/DA
      LIA=L6*IA
      JNUM=J*NUMP
      JKNM=JNUM-NUM1
      DO 200 K=JKNM,JNUM
      IB=(B(K)-BMN)/DB
      JZZ=(K-JPQ)/NREP
      ISYM=JZZ-(JZZ/NSYM)*NSYM+1
      CALL PFIX(P,IB,LIA,SYM(ISYM))
  200 CONTINUE
      DO 300 J=1,M
      JQ=(J/10)*10
      JLO=J*L6-LQ
      JHI=JLO+LQ
      WRITE(6,1000) (P(K),K=JLO,JHI)
      IF(J.EQ.JZA) WRITE(6,1550) ZRO,(Q(K),K=1,20)
      IF(JQ.NE.J) GO TO 300
      DAJ=AMN+DA*(J-1)
      WRITE(6,1550) DAJ,(Q(K),K=1,20)
  300 CONTINUE
 1000 FORMAT(15X,1HI,19A6)
 1550 FORMAT(1H+,G13.5,2X,20A5)
      WRITE(6,2021) (H(J),J=1,L10)
      RETURN
      END
      SUBROUTINE RANGE(A,N,AMX,AMN,JMX,JMN)
      DIMENSION A(1)
      AMX=A(1)
      AMN=A(1)
      JMX=1
      JMN=1
      DO 100 J=2,N
      IF(A(J).LT.AMX) GOTO 50
      JMX=J
      AMX=A(J)
 50   CONTINUE
      IF(A(J).GT.AMN) GOTO 100
      JMN=J
      AMN=A(J)
 100  CONTINUE
      RETURN
      END
```

vv

```
      SUBROUTINE NORM(A,B,N,C1,C2,AMX,AMN)
      DIMENSION A(1),B(1)
      CALL RANGE(A,N,AMX,AMN,JMX,JMN)
      CC=C1-C2
      X=(AMX-AMN)/CC
      IF(X.EQ.0.)X=1.
      Y=(C1*AMN-C2*AMX)/CC
     Z=1./X
      DO 100 J=1,N
      B(J)=(A(J)-Y)*Z
  100 CONTINUE
      RETURN
      END
vv
```

```
      SUBROUTINE PFIX(P,IB,LIA,SYM)
      DIMENSION BUF(6),P(1)
      IB6=IB/6
      LIB=LIA+IB6+1
      DECODE(6,1000,P(LIB)) BUF
 1000 FORMAT(6A1)
      IRES=IB-6*IB6+1
      BUF(IRES)=SYM
      ENCODE(6,1000,P(LIB)) BUF
      RETURN
      END
```

vv

APPENDIX B

GRAPHIC OUTPUTS

(See Tables 6.1 through 6.4 and Section 6.4
for explanation)

The results presented in this appendix may not be exactly reproduced by running the program listed in Appendix A due to i) a difference in computer system, and ii) some of the runs in Appendix B may have been obtained with an earlier version of the program.

RUN D-L-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0300E+00  1.0300E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.         V  1.0000E+00 W  0.
     K    1  L    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION
                           2.0000E-01
FALL VELOCITY OF SOLID
                           5.0000E-02
```

RUN D-L-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0290E+00  1.0290E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2   1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                          5.0000E-02
```

RUN D-L-3

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0280E+00  1.0280E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.



BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2    1.0000
ALPHA0      .2350 BETA    0.0000 CM    1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.         V  1.0000E+00 W  0.
      K    1  1     1
DENSITY OF SOLID            2.5000E+00
CONCENTRATION

                            2.0000E-01
FALL VELOCITY OF SOLID
                            5.0000E-02
```

RUN D-L-4

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0270E+00  1.0270E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1     1 KEY2     2 KEY3     0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
      K    1  1     1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION
                           2.0000E-01
FALL VELOCITY OF SOLID
                           5.0000E-02
```

RUN D-L-5

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
      K   1  1    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION
                           2.0000E-01
FALL VELOCITY OF SOLID
                           5.0000E-02
```

RUN D-L-6

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0250E+00  1.0250E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.        V  1.0000E+00 W  0.
       K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                          5.0000E-02
```

RUN D-L-7

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH               0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY         1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK
                    3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1     1 KEY2     2 KEY3     0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
     K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION

                          2.0000E-01
FALL VELOCITY OF SOLID

                          5.0000E-02
```

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RUN D-L-8

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YH 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0      .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 RHO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                          5.0000E-02
```

RUN D-L-9

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.         V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID            2.5000E+00
CONCENTRATION
                            2.0000E-01
FALL VELOCITY OF SOLID
                            5.0000E-02
```

RUN D-L-10

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.             4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 1.0000E+00


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  3.6000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0      .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN      .0100 F1      .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.3000E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                          5.0000E-02
```

RUN D-L-11

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0300E+00  1.0300E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.



BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2   1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.3000E+00 U  1.0000E+00 V  1.0000E+00 W  1.0000E+00
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                          5.0000E-02
```

RUN D-S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0280E+00  1.0280E+00


VK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RR  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
     K    1  1    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION
                            1.5000E-01
FALL VELOCITY OF SOLID
                            5.0000E-03
```

RUN D-S-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0270E+00  1.0270E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RP  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
     K    1  I    1
DENSITY OF SOLID             1.8000E+00
CONCENTRATION

                             1.5000E-01
FALL VELOCITY OF SOLID
                             5.0000E-03
```

RUN D-S-3

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  2.1000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHAO     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.         V  1.0000E+00 W  0.
       K   1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-S-4

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0250E+00  1.0250E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

FB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID             1.8000E+00
CONCENTRATION
                             1.5000E-01
FAIL VELOCITY OF SOLID
                             5.0000E-03
```

RUN D-S-5

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH             0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-S-6

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE    51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RR  5.0000E+00 ROO  1.1200E+00 U  0.         V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-S-7

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1     1 KEY2     2 KEY3     0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K     1  L     1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-S-8

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 1.0000E+00


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RP  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION
                            1.5000E-01
FALL VELOCITY OF SOLID
                            5.0000E-03
```

RUN D-S-9

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  0.         W  0.
      K     1  1    1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION

                           1.5000E-01
FALL VELOCITY OF SOLID
                           5.0000E-03
```

RUN D-S-10

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHAO      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RH  5.0000E+00 ROO  1.1200E+00 U  0.          V  5.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION
                            1.5000E-01
FALL VELOCITY OF SOLID
                            5.0000E-03
```

RUN D-S-11

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.          4.0000E+01  6.0000E+01  6.5000E+01
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.0000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 6.5000E+01H 6.5000E+01
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+02SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCH1     1.0000 DINCH2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2     1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.           V  5.0000E+00 W  0.
      K    1  L     1
DENSITY OF SOLID             1.8000E+00
CONCENTRATION

                             1.5000E-01
FALL VELOCITY OF SOLID

                             5.0000E-03
```

RUN D-S-12

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.             4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  1.0000E+01 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
     K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-S-13

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1   10.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
       K    1  1     1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION
                            1.5000E-01
FALL VELOCITY OF SOLID
                            5.0000E-03
```

RUN D-S-14

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1    1.0000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION

                            1.5000E-01
FALL VELOCITY OF SOLID
                            5.0000E-03
```

RUN D-S-15

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .5000 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.         V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION
                           1.5000E-01
FALL VELOCITY OF SOLID
                           5.0000E-03
```

RUN D-S-16

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHAO     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN    0.0000 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.         V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID             1.8000E+00
CONCENTRATION
                             1.5000E-01
FALL VELOCITY OF SOLID
                             5.0000E-03
```

RUN D-S-17

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


VK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2    1.0000
ALPHAO      .2350 BETA    0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .100 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1     .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.         V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION
                           1.5000E-01
FALL VELOCITY OF SOLID
                           5.0000E-03
```

RUN D-S-18

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM      1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .1000
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  1    1
DENSITY OF SOLID              1.8000E+00
CONCENTRATION

                              1.5000E-01
FALL VELOCITY OF SOLID

                              5.0000E-03
```

RUN D-S-19

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0260E+00  1.0260E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02 [illegible]0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE    51 KEY1     2 KEY2     2 KEY3     0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     0.0000
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2     1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1200E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION
                          1.5000E-01
FALL VELOCITY OF SOLID
                          5.0000E-03
```

RUN D-LL-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH                0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY         1.0230E+00  1.0230E+00  1.0230E+00  1.0230E+00


YK                   3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                   5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.          KA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  2.5000E+02SEC.

GRID POINT SIZE   51 KEY1     1 KEY2     3 KEY3     1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0       .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.0500E+00 U  0.          V  6.0000E-01 W  0.
      K    1  L    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION

                           2.0000E-01
FALL VELOCITY OF SOLID

                           5.0000E-01
```

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RUN D-F-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0231E+00  1.0231E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YO 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  2.5000E+02SEC.

GRID POINT SIZE    51 KEY1     1 KEY2     5 KEY3     0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA     0.0000 CM     1.0000 CD      .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1     1.0000 ALFA2     1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

RB  5.0000E+00 RHOB  1.0500E+00 U  0.          V  6.0000E-01 W  0.
       N    I  L     1
DENSITY OF SOLID            1.0230E+00
CONCENTRATION
                            0.
FALL VELOCITY OF SOLID
                            0.
```

RUN D-FS-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            2.0000E+01  4.0000E+01  1.0000E+02
AMB-DENSITY     1.0200E+00  1.0200E+00  1.0300E+00  1.0350E+00


YK                1.8000E+01  2.2000E+01  3.8000E+01  4.2000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 2.0000E+01YW 2.0000E+01YE 4.0000E+01H 1.0000E+02
UA 1.0000E+00WA 0.



BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  3.6000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROO  1.1000E+00 U  0.          V  1.0000E+00 W  0.
        K    1  L    1
DENSITY OF SOLID          1.0000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                         -1.0000E-02
```

RUN D-FS-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           2.0000E+01  4.0000E+01  1.0000E+02
AMB-DENSITY      1.0200E+00  1.0200E+00  1.0300E+00  1.0350E+00


YK                1.8000E+01  2.2000E+01  3.8000E+01  4.2000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 2.0000E+01YM 2.0000E+01YE 4.0000E+01H 1.0000E+02
UA 1.0000E+00WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  2.0000E+03SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    3 KEY3    1

USE READ IN COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA0     .2350 BETA    0.0000 CM    1.0000 CD     .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC     .0010
FRICTN     .0100 F1     .1000
ALFA1   1.0000 ALFA2    1.0000 GAMA1     .0200 GAMA2    0.0000
ALAMDA     .0010

RB  5.0000E+00 ROU  1.1000E+00 U  0.          V  1.0000E+00 W  0.
      K    1  L    1
DENSITY OF SOLID          1.0000E+00
CONCENTRATION
                          2.0000E-01
FALL VELOCITY OF SOLID
                         -1.0000E-02
```

RUN D-2S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0245E+00


YM              3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY              5.0000E-02  5.0000E-03  1.0000E-02

YU 3.0000E+01YM 4.0000E+01YF 5.0000E+01H 1.0000E+02
UA 1.0000E+00WA 0.


BARGE OPERATION 1

WASTE MATERIAL DUMPED INSTANTANEOUSLY INTO THE OCEAN

THE SHAPE OF THE CLOUD IS ASSUMED TO BE HEMISPHERE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1     2 KEY2     2 KEY3     0

USE READ IN COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA0      .2350 BETA    0.0000 CM     1.0000 CD       .5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .10 CD4 1.00 ALPHAC      .0010
FRICTN      .0100 F1      .1000
ALFA1    1.0000 ALFA2    1.0000 GAMA1      .1000 GAMA2    0.0000
ALAMDA      .0010

RB  5.0000E+00 ROO  1.1300E+00 U  0.          V  1.0000E+00 W  0.
      K    2  L    1
DENSITY OF SOLID             9.0000E-01  2.5000E+00
CONCENTRATION
                             2.0000E-01  1.0000E-01
FALL VELOCITY OF SOLID
                            -5.0000E-02  5.0000E-02
```

RUN J-L-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.          3.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY        1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2      .3536  BETA     0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4     .0010 FRICTN       .0100 F1      .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS          .5000  DENSITY    1.3000  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K   1  L   1
DENSITY OF SOLID              2.5000E+00
CONCENTRATION                 2.0000E-01
FALL VELOCITY OF SOLID    5.0000E-02
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU      YW       YE      H
  7.5000  7.5000           7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-L-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2      .3536  BETA     0.0000 CD      1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4     .0010 FRICIN      .0100 F1      .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS        .5000  DENSITY    1.3000  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION             2.0000E-01
FALL VELOCITY OF SOLID    5.0000E-02
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    D       YU       YW       YE       H
  7.5000  7.5000            7.5000  7.5000
 -0.0000           0.0000 -0.0000 -0.0000
```

RUN J-L-3

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0231E+00  1.0231E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS        .5000  DENSITY    1.3000  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
       K    1  L    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION              2.0000E-01
FALL VELOCITY OF SOLID     5.0000E-02
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YW       YE       H
   7.5000  7.5000           7.5000  7.5000
  -0.0000           0.0000 -0.0000 -0.0000
```

RUN J-L-4

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH               0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YN 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA    0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS       .5000  DENSITY    1.3000  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
       K    1  L    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION              2.0000E-01
FALL VELOCITY OF SOLID     5.0000E-02
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YN       YE       H
   8.5000  8.5000           7.5000  7.5000
  -0.0000          0.0000 -0.0000 -0.0000
```

Reproduced from best available copy.

RUN J-L-5

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH           0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 1.0000E+00KA 1.0000E+00



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA    0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3       .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS        .5000  DENSITY    1.3000  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
       *    1  1    1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION              2.0000E-01
FALL VELOCITY OF SOLID    5.0000E-02
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     D      YU       YW       YF      H
  8.5000  8.5000           7.5000  7.5000
 -0.0000          1.0000 -0.0000 -0.0000
```

Reproduced from best available copy.

RUN J-S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK              3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY              5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS      .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K   1 L   1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U       YU       YW       YE       H
   7.5000  7.5000            7.5000  7.5000
  -0.0000           0.0000 -0.0000 -0.0000
```

RUN J-S-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YM                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YM 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1   1.0000 ALFA2   1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS       .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YM       YF       H
  7.5000  7.5000           7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-S-3

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0231E+00  1.0231E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YO 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

ISTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA     0.0000 CD     1.5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM     1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS          .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY     5.0000 AT   10.0000 FT.
       K    1  L    1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION              1.5000E-01
FALL VELOCITY OF SOLID     5.0000E-03
BARGE VELOCITY     7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U        YO        YW        YF       H
   7.5000  7.5000             7.5000  7.5000
  -0.0000            0.0000 -0.0000 -0.0000
```

RUN J-S-4

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0230E+00  1.0230E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1      .1000 CM    1.0000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS       .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU       YW       YE       H
  7.5000  7.5000           7.5000  7.5000
 -0.0000           0.0000 -0.0000 -0.0000
```

RUN J-S-5

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA     0.0000 CM     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CK    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

JET RADIUS       .5000  DENSITY    1.1200  ANGLE OF JET     0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION               1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU       YW       YF      H
  8.5000  8.5000           7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-S-6

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH              0.            3.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YO 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 1.0000E+00



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.5000E+04SEC.

GRID POINT SIZE   51 KEY1     1 KEY2     5 KEY3     1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA     0.0000 CD     1.5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM     1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS         .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
       K    1  L    1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION              1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U       YO       YW       YF       H
  8.5000  8.5000             7.5000  7.5000
 -0.0000            1.0000 -0.0000 -0.0000
```

RUN J-S-7

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.             4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA     0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM     1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

JET RADIUS       1.0000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
        K    1  1    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION               1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU       YW       YE       H
  7.5000  7.5000           7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-S-8

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS        .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY   10.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU      YW       YE      H
  7.5000  7.5000          7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-S-9

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.              4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                  3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                  5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1   1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS       .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   20.0000 FT.
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU      YW       YE      H
  7.5000  7.5000           7.5000  7.5000
 -0.0000          0.0000 -0.0000 -0.0000
```

RUN J-S-10

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA     0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM     1.0000
ALFA1    1.0000 ALFA2     1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

JET RADIUS         .5000  DENSITY     1.1200  ANGLE OF JET     0.0000
VELOCITY     5.0000 AT    10.0000 FT.
       K     1  L     1
DENSITY OF SOLID           1.8000E+00
CONCENTRATION              1.5000E-01
FALL VELOCITY OF SOLID     5.0000E-03
BARGE VELOCITY     5.0000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0        YU        YW        YE       H
  5.0000  5.0000              5.0000  5.0000
 -0.0000             0.0000 -0.0000 -0.0000
```

RUN J-S-11

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH             0.              4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY       1.0230E+00  1.0230E+00  1.0235E+00  1.0235E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CH    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS        .5000  DENSITY    1.1200  ANGLE OF JET   45.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION               1.5000F-01
FALL VELOCITY OF SOLID    5.0000E-03
BARGE VELOCITY    5.0000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0        YU       YW        YF       H
  5.0000  5.0000            5.0000  5.0000
 -0.0000            0.0000 -0.0000 -0.0000
```

RUN J-S-12

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH               0.             4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY         1.0250E+00  1.0250E+00  1.0231E+00  1.0231E+00
                                                              ^
                                                              1
YK
KY                    3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
                      5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     1.0000 DINCR2     1.0000
ALPHA1      .0806  ALPHA2       .3536  BETA    0.0000 CD     1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3       .3536
ALPHA4      .0010 FRICTN       .0100 F1       .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

JET RADIUS          .5000  DENSITY     1.1200  ANGLE OF JET     0.0000
VELOCITY     5.0000 AT   10.0000 FT.
       K     1  L     1
DENSITY OF SOLID             1.8000E+00
CONCENTRATION                1.5000E-01
FALL VELOCITY OF SOLID     5.0000E-03
BARGE VELOCITY     7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0        YU        YW        YF        H
  7.5000  7.5000              7.5000  7.5000
 -0.0000              0.0000 -0.0000 -0.0000
```

RUN J-F-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCH1    1.0000 DINCH2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.5000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CF    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS        .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID         1.0000E+00
CONCENTRATION            0.
FALL VELOCITY OF SOLID   0.
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  225.0000 DEGREES FOR1.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U       YU       YW       YE       H
   5.3033  5.3033           5.3033  5.3033
   5.3033          5.3033  5.3033  5.3033
```

RUN J-F-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.              4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                 3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                 5.0000E-02  5.0000E-03  1.0000E-02

YO 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 1.0000E+00



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCH1     1.0000 DINCH2     1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

JET RADIUS         .5000  DENSITY    1.1200  ANGLE OF JET    0.0000
VELOCITY    5.0000 AT   10.0000 FT.
      K    1  L    1
DENSITY OF SOLID            1.0000E+00
CONCENTRATION               0.
FALL VELOCITY OF SOLID      0.
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  225.0000 DEGREES FOR5.0000E+01 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U       YO        YW        YE       H
   6.3033  6.3033            5.3033  5.3033
   5.3033            6.3033  5.3033  5.3033
```

RUN J-2S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0245E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 3.0000E+01YW 4.0000E+01YE 5.0000E+01H 1.0000E+02
UA 1.0000E+00WA 0.



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    2 KEY2    2 KEY3    1
USE READ IN COEFFICIENTS
DINCR1    1.0000 DINCR2    1.0000
ALPHA1      .0806  ALPHA2      .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4     .0010 FRICTN     .0010 F1     .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1     .1000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS       .5000  DENSITY    1.1300  ANGLE OF JET    0.0000
VELOCITY    7.5000 AT   10.0000 FT.
       K    2  L    1
DENSITY OF SOLID              2.5000E+00
CONCENTRATION                 1.0000E-01
FALL VELOCITY OF SOLID        5.0000E-02
DENSITY OF SOLID              9.0000E-01
CONCENTRATION                 2.0000E-01
FALL VELOCITY OF SOLID       -5.0000E-02
BARGE VELOCITY    5.0000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR6.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    D       YU      YW       YE       H
  6.0000  6.0000           5.0000  5.0000
  -.0000          -.0000  -.0000  -.0000
```

RUN J-4S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.             4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0240E+00  1.0240E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 1.0000E+00WA 1.0000E+00



BARGE OPERATION 2
DISCHARGE THROUGH A NOZZLE UNDER A MOVING BARGE

TSTOP  1.5000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1    1.0000 DINCR2    1.0000
ALPHA1     .0806  ALPHA2     .3536  BETA    0.0000 CD    1.3000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 CM    1.0000
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

JET RADIUS        .5000  DENSITY    1.2000  ANGLE OF JET    0.0000
VELOCITY    5.0000 A1   10.0000 FT.
      K    2 L    2
DENSITY OF SOLID            1.0000E+00
CONCENTRATION               1.0000E-01  2.0000E-01
FALL VELOCITY OF SOLID     -1.0000E-01 -1.0000E-03
DENSITY OF SOLID            2.0000E+00
CONCENTRATION               1.5000E-01  5.0000E-02
FALL VELOCITY OF SOLID      1.5000E-01  1.5000E-03
BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
    0       YU       YW        YE      H
  8.5000  8.5000             7.5000  7.5000
 -0.0000           1.0000 -0.0000 -0.0000
```

RUN W-L-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH            0.          4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY      1.0230E+00  1.0230E+00  1.0232E+00  1.0232E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE.
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+03SEC.

GRID POINT SIZE    51 KEY1     1 KEY2     2 KEY3     1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2     1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA        .3536 BETA     0.0000 CD1       .5000 CD2     1.3000 CM     1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1       .1000 ALPHA1      .0806
ALFA1    1.0000 ALFA2     1.0000 GAMA1     0.0000 GAMA2     0.0000
ALAMDA      .0010

 DENSITY     1.3000 DISCHARGE RATE   10.0000 BARGE WIDTH      25.00 BARGE DEPTH      10.00
       K     1  L     1
DENSITY OF SOLID            2.5000E+00
CONCENTRATION               2.0000E-01
FALL VELOCITY OF SOLID      5.0000E-02

BARGE VELOCITY     7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     U        YU       YW        YE       H
UA   7.500   7.500              7.500   7.500
WA  -0.000            0.000  -0.000  -0.000
```

RUN W-L-2

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH            0.          1.0000E+02
AMB-DENSITY      1.0230F+00  1.0230F+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000F+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPFRATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA      .3536 BETA    0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1      .1000 ALPHA1     .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

 DENSITY    1.3000 DISCHARGE RATE   10.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
      K    1  L    1
DENSITY OF SOLID            2.5000E+00
CONCENTRATION               2.0000E-01
FALL VFLOCITY OF SOLID      5.0000F-02

BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0        YU       YW       YE       H
UA   7.500   7.500             7.500   7.500
WA  -0.000             0.000  -0.000  -0.000
```

RUN W-L-3

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.           4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0232E+00  1.0232E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA       .3536 BETA    0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4      .0010 FRICTN     .0100 F1      .1000 ALPHA1     .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

 DENSITY    1.3000 DISCHARGE RATE   10.0000 BARGE WIDTH     10.00 BARGE DEPTH     10.00
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION             2.0000E-01
FALL VELOCITY OF SOLID    5.0000E-02

BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YW       YE       H
UA   7.500   7.500             7.500   7.500
WA  -0.000            0.000  -0.000  -0.000
```

RUN W-L-4

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0232E+00  1.0232E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.         WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    0

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1     .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA      .3536 BETA    0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 ALPHA1     .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

 DENSITY    1.3000 DISCHARGE RATE  100.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
      K    1  L    1
DENSITY OF SOLID          2.5000E+00
CONCENTRATION             2.0000E-01
FALL VELOCITY OF SOLID    5.0000E-02

BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU      YW      YE      H
UA   7.500   7.500           7.500   7.500
WA  -0.000           0.000  -0.000  -0.000
```

RUN W-L-5

```
 AMBIENT CONDITIONS
DEPTH IN FT,  DENSITY IN GRAM PER CC,  KY IN SQFT PER SEC,  VEL, IN FPS,
DEPTH           0,            4,0000E+01  6,0000E+01  1,0000E+02
AMB-DENSITY     1,0230E+00  1,0230E+00  1,0232E+00  1,0232E+00


YK               3,5000E+01  4,5000E+01  5,5000E+01  6,5000E+01
KY               5,0000E-02  5,0000E-03  1,0000E-02

YU 5,0000E+01YW 5,0000E+01YE 1,0000E+02H 1,0000E+02
UA 0,        WA 0,


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1,0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4,00
ALPHA       .3536 BETA    0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 ALPHA1      .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA      .0010

 DENSITY    1.3000 DISCHARGE RATE   10.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
      K     1  L     1
DENSITY OF SOLID           2.5000E+00
CONCENTRATION              2.0000E-01
FALL VELOCITY OF SOLID     5.0000E-02

BARGE VELOCITY    5.0000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YW       YE       H
UA   5.000   5.000             5.000   5.000
WA  -0.000            0.000  -0.000  -0.000
```

RUN W-S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0232E+00  1.0232E+00


YK                3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY                5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YF 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+03SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    2 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA       .3536 BETA    0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 ALPHA1      .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALANDA      .0010

 DENSITY    1.1200 DISCHARGE RATE   10.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
       K    1  L    1
DENSITY OF SOLID            1.8000E+00
CONCENTRATION               1.5000E-01
FALL VELOCITY OF SOLID      5.0000E-03

BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
      0       YU       YW       YF       H
UA   7.500   7.500             7.500   7.500
WA  -0.000            0.000  -0.000  -0.000
```

RUN W-S-2

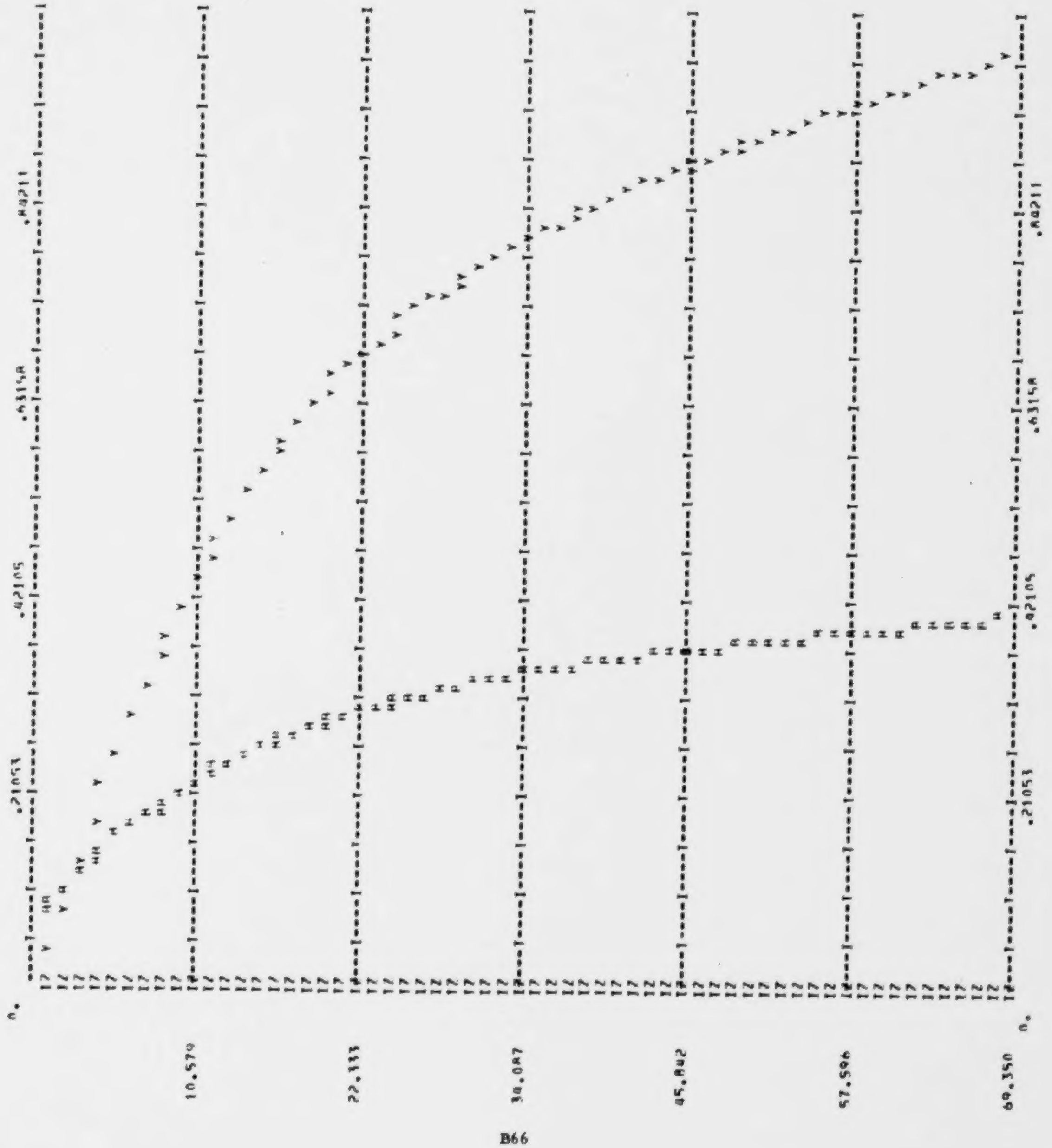
```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SOFT PER SEC.  VEL. IN FPS.
DEPTH           0.          1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  5.0000E+04SEC.

GRID POINT SIZE   51 KEY1    1 KEY2    3 KEY3    1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2    1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA      .3536 BETA    0.0000 CD1     .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3     .3536
ALPHA4     .0010 FRICTN     .0100 F1     .1000 ALPHA1     .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1    0.0000 GAMA2    0.0000
ALAMDA     .0010

 DENSITY    1.1200 DISCHARGE RATE   10.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
      K    1  L    1
DENSITY OF SOLID          1.8000E+00
CONCENTRATION             1.5000E-01
FALL VELOCITY OF SOLID    5.0000E-03

BARGE VELOCITY    7.5000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0        YU       YW       YE       H
UA   7.500   7.500            7.500   7.500
WA  -0.000            0.000  -0.000  -0.000
```

RUN W-4S-1

```
 AMBIENT CONDITIONS
DEPTH IN FT.  DENSITY IN GRAM PER CC.  KY IN SQFT PER SEC.  VEL. IN FPS.
DEPTH           0.            4.0000E+01  6.0000E+01  1.0000E+02
AMB-DENSITY     1.0230E+00  1.0230E+00  1.0232E+00  1.0232E+00


YK               3.5000E+01  4.5000E+01  5.5000E+01  6.5000E+01
KY               5.0000E-02  5.0000E-03  1.0000E-02

YU 5.0000E+01YW 5.0000E+01YE 1.0000E+02H 1.0000E+02
UA 0.        WA 0.


BARGE OPERATION 3

WASTE MATERIAL IS DISCHARGED CONTINUOUSLY INTO THE BARGE WAKE,
AFTER THE INITIAL MIXING, THE WASTE MATERIAL IS ASSUMED
TO BE IN A FORM OF HALF CYLINDER THERMAL.


TSTOP  1.0000E+04SEC.

GRID POINT SIZE    51 KEY1     1 KEY2     2 KEY3     1

USE TETRA TECH SUGGESTED COEFFICIENTS

DINCR1      .2500 DINCR2     1.0000

BARGE SHAPE FACTORS C1  .60 C2 4.00
ALPHA       .3536 BETA     0.0000 CD1      .5000 CD2    1.3000 CM    1.0000
GAMA  .25 CDRAG 1.00 CFRIC .010 CD3  .20 CD4 2.00 ALPHA3      .3536
ALPHA4      .0010 FRICTN      .0100 F1      .1000 ALPHA1      .0806
ALFA1    1.0000 ALFA2    1.0000 GAMA1     0.0000 GAMA2    0.0000
ALAMDA      .0010

 DENSITY    1.2000 DISCHARGE RATE   10.0000 BARGE WIDTH     25.00 BARGE DEPTH     10.00
      K    2  L    2
DENSITY OF SOLID           1.0000E+00
CONCENTRATION              1.0000E-01  2.0000E-01
FALL VELOCITY OF SOLID   -1.0000E-01 -1.0000E-03
DENSITY OF SOLID           2.0000E+00
CONCENTRATION              1.5000E-01  5.0000E-02
FALL VELOCITY OF SOLID     1.5000E-01  1.5000E-03

BARGE VELOCITY     5.0000 ANGLE WITH X-AXIS  180.0000 DEGREES FOR5.0000E+02 SEC.

AMBIENT CURRENT FOR A MOVING COORDINATE FIXED ON THE BARGE
     0       YU       YW       YE       H
UA   5.000   5.000             5.000   5.000
WA  -0.000            0.000  -0.000  -0.000
```

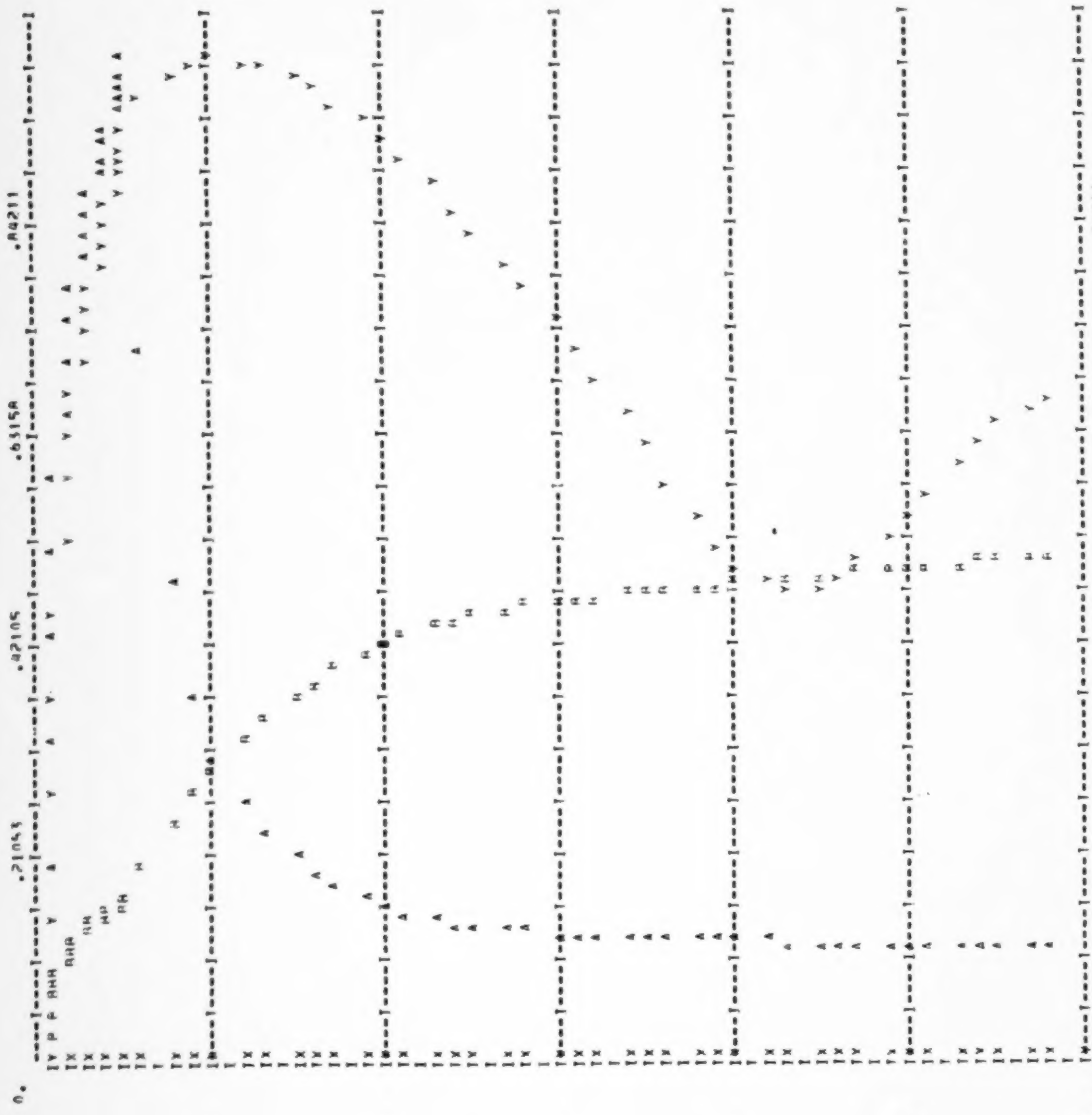
RUN-D-L-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          69.350

                       DEPENDENT VARIABLES

SYMBOL              Y               R              X             Z
MAX PLOTTED     90.243          26.207          0.            0.
MIN PLOTTED     0.              0.              0.            0.
REMARKS         VERT. DIST.     RADIUS         HOR. DIST.    HOR. DIST.
```



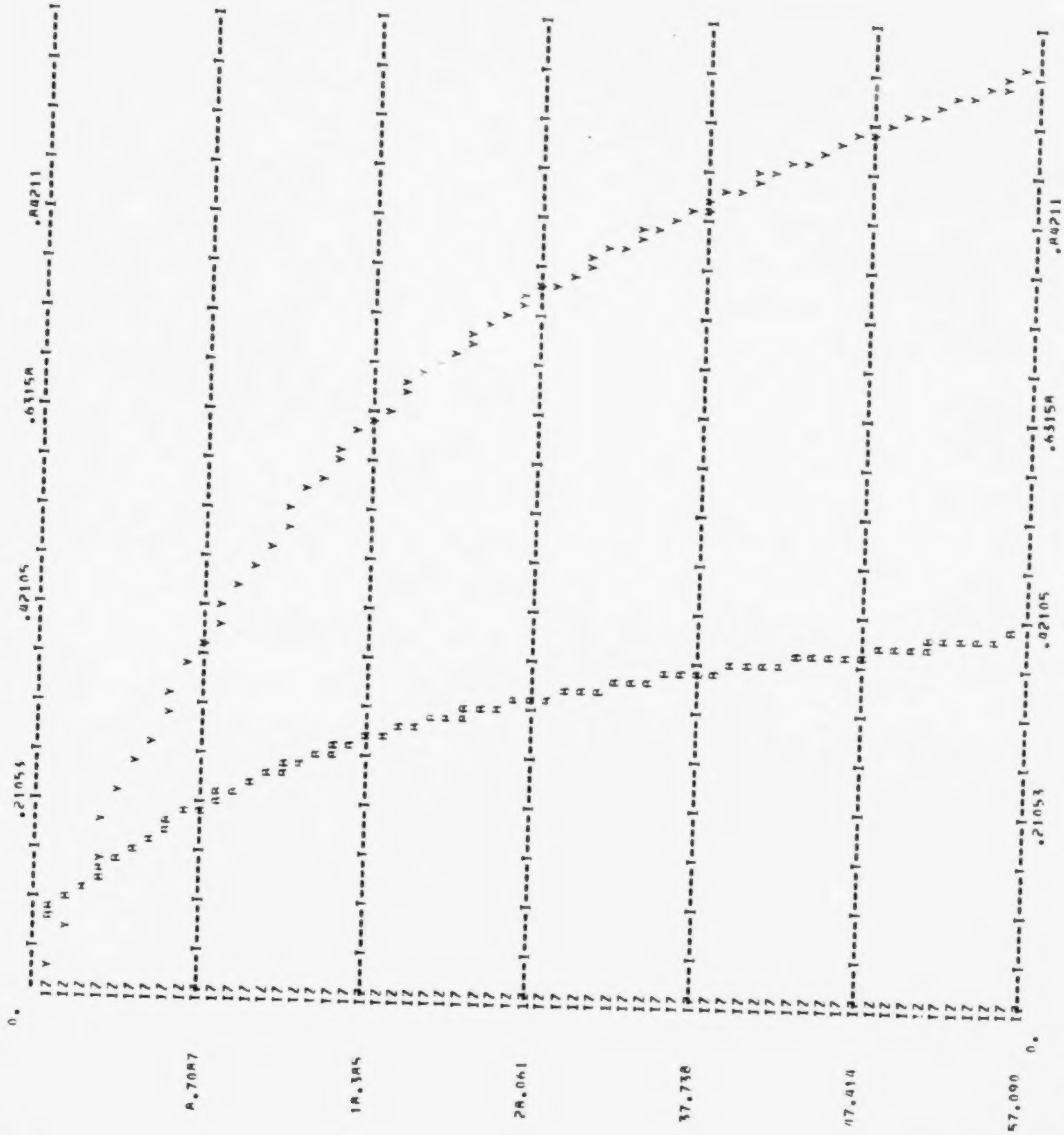
RUN D-L-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           805.90

                      DEPENDENT VARIABLES

SYMBOL              A               B             X             Y
MAX PLOTTED     13.039          81.919       0.              96.623
MIN PLOTTED     0.              0.           0.              0.
REMARKS         VERT. SIZE.     HOR. SIZE     HOR. DIST.     VERT. DIST.
```



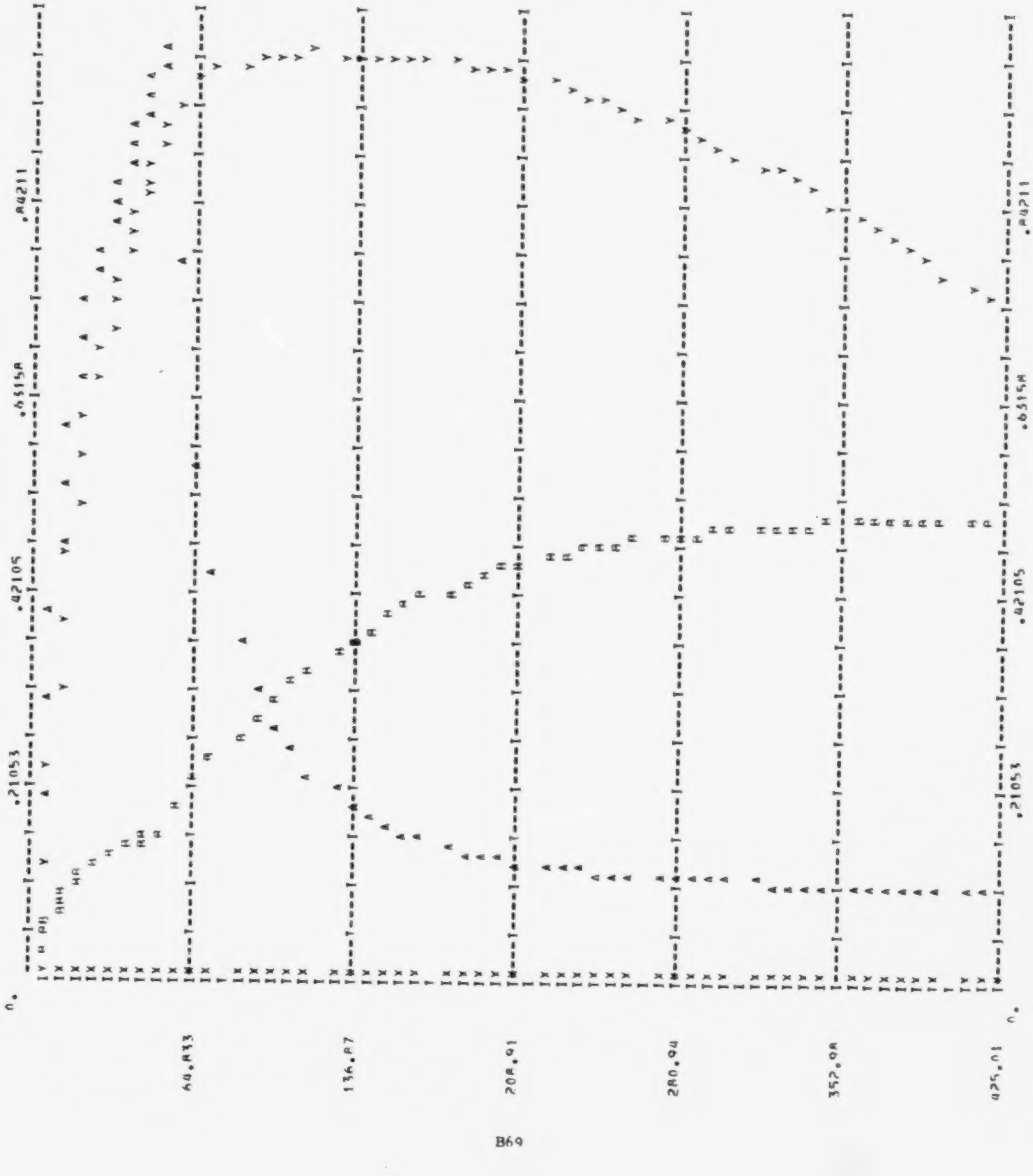
RUN D-L-2

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          57.090

                        DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED     90.299         26.220          0.             0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



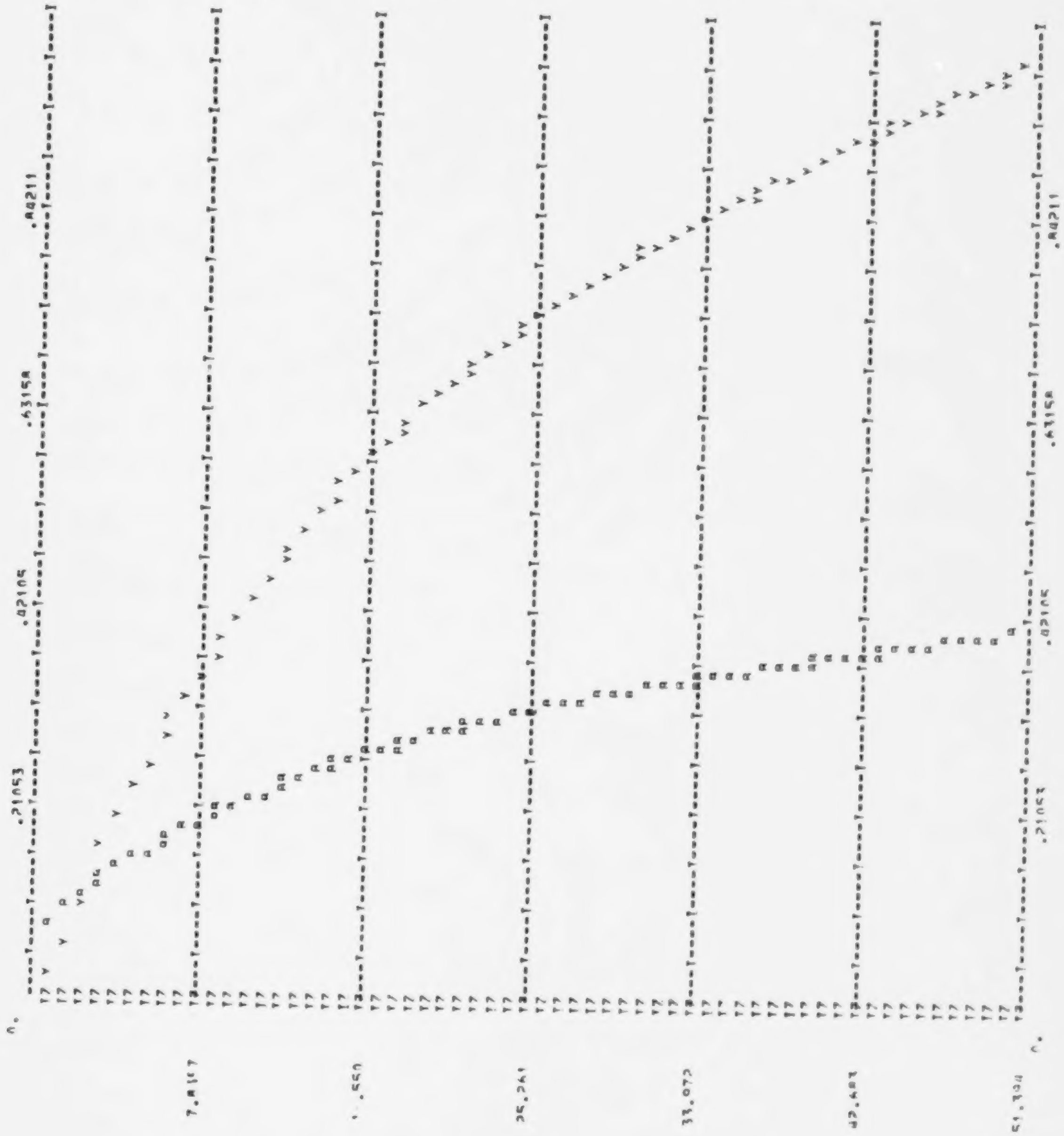
RUN D-L-2

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.           425.01

                        DEPENDENT VARIABLES

SYMBOL              A              B             X              Y
MAX PLOTTED     13.025         83.697       0.               97.808
MIN PLOTTED    0.             0.            0.              0.
REMARKS        VERT. SIZE.    HOR. SIZE     HOR. DIST.     VERT. DIST.
```



RUN D-L-3

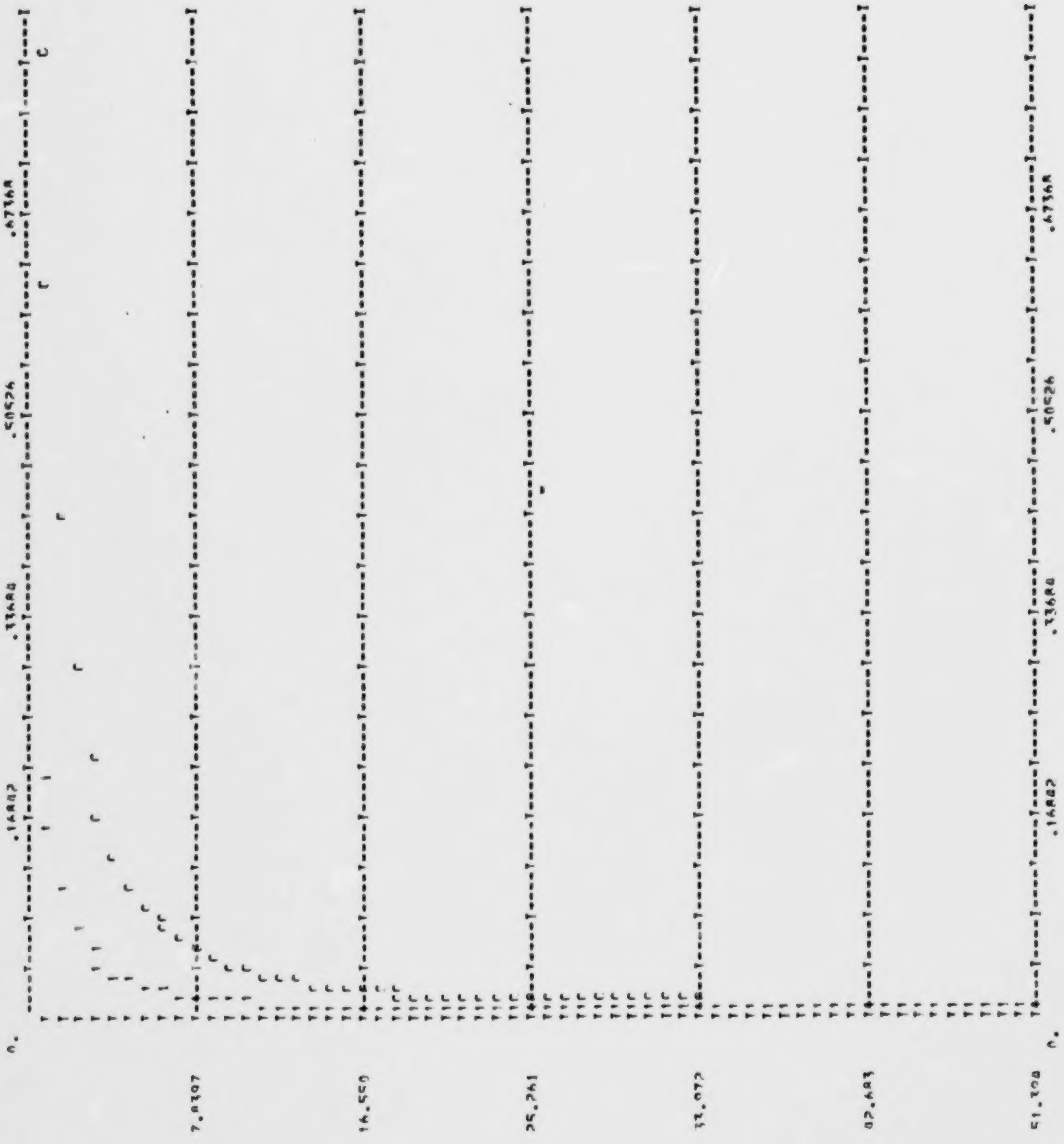
```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          51.398

                          DEPENDENT VARIABLES

SYMBOL              Y             R             X             Z
MAX PLOTTED      90.365        26.236        0.            0.
MIN PLOTTED      0.            0.            0.            0.
REMARKS          VERT. DIST.    RADIUS       HOR. DIST.    HOR. DIST.
```



RUN D-L-3

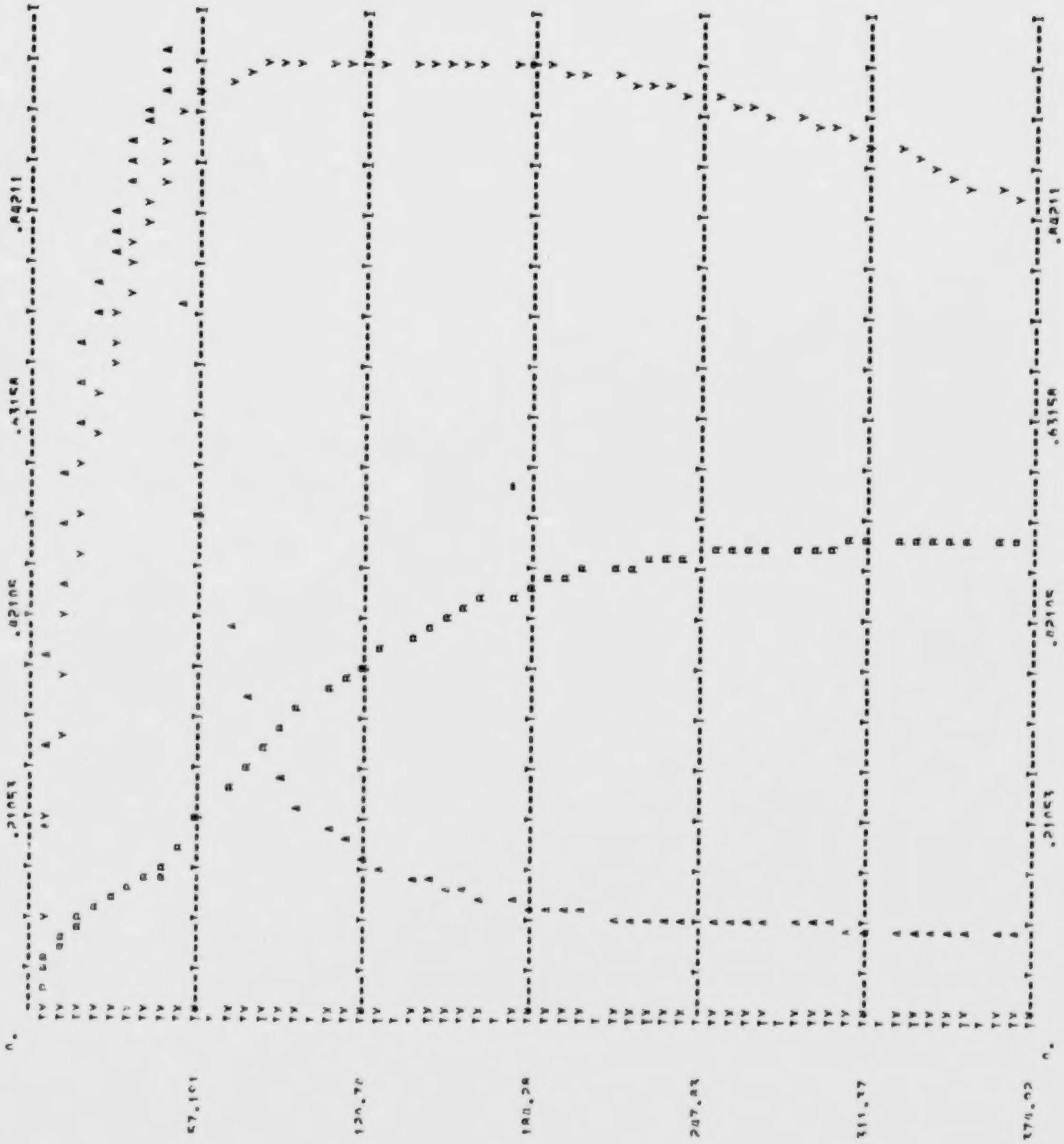
GRAPH OF WASTE CONCENTRATIONS

RANGE OF X 0. 51.393536
RANGE OF CONCENTRATIONS PLOTTED 0. .80000000



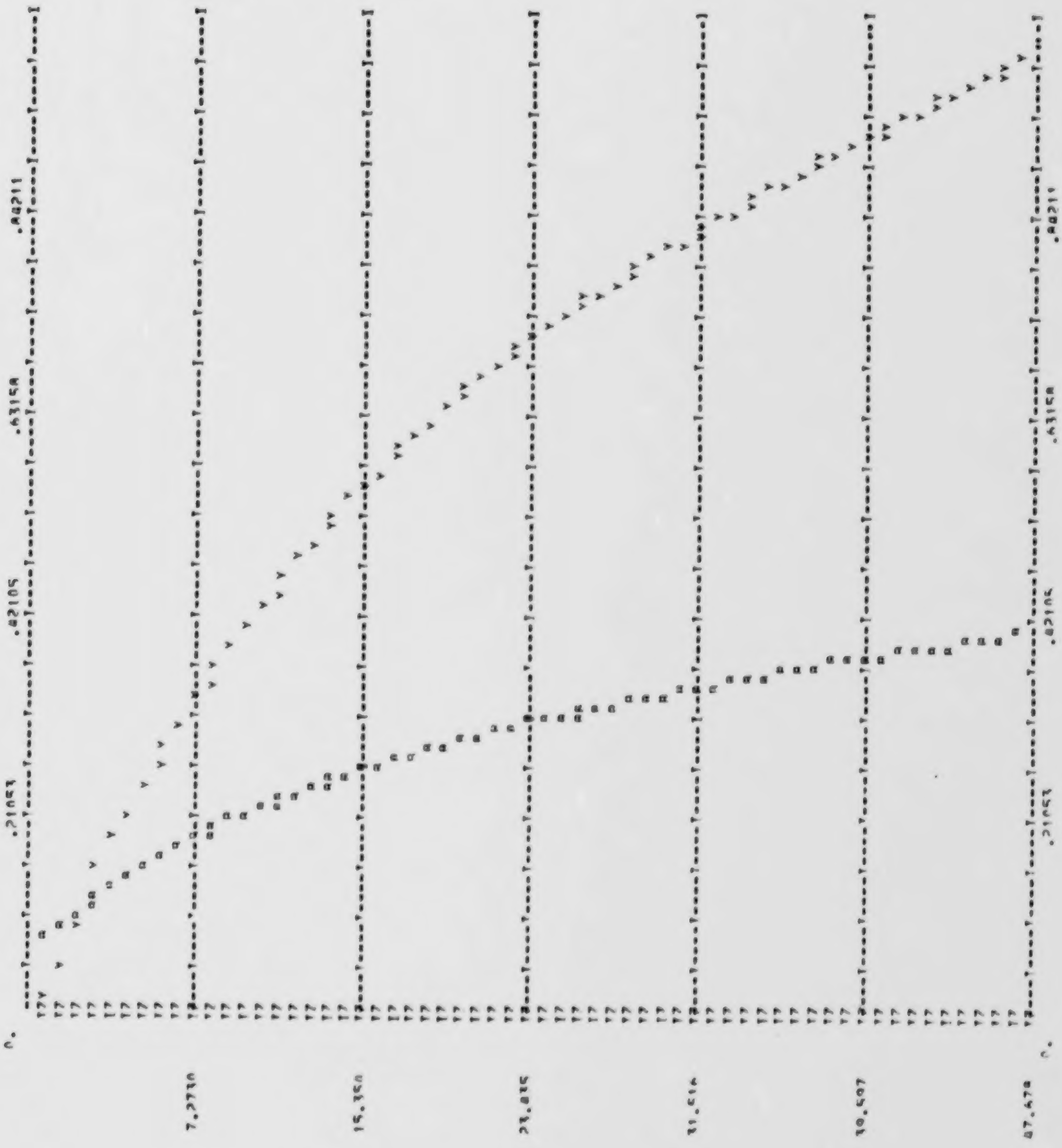
RUN D-L-3

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          374.92

                           DEPENDENT VARIABLES

SYMBOL                A               B              X              Y
MAX PLOTTED        13.021          87.679         0.            98.407
MIN PLOTTED     0.              0.              0.            0.
REMARKS         VERT. SIZE.     HOR. SIZE      HOR. DIST.    VERT. DIST.
```



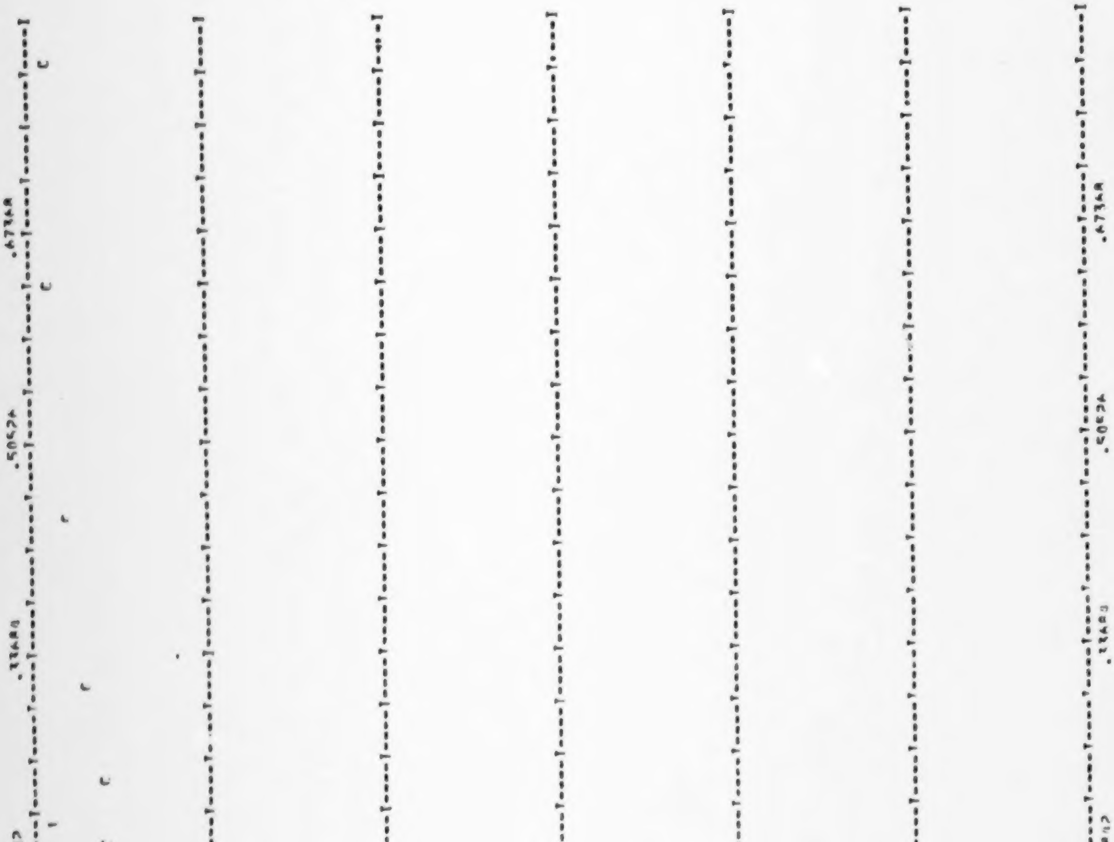
RUN D-L-4

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           47.678

                    DEPENDENT VARIABLES

SYMBOL               Y              R              X              Z
MAX PLOTTED      90.314         26.224         0.             0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.     RADIUS        HOR. DIST.     HOR. DIST.
```



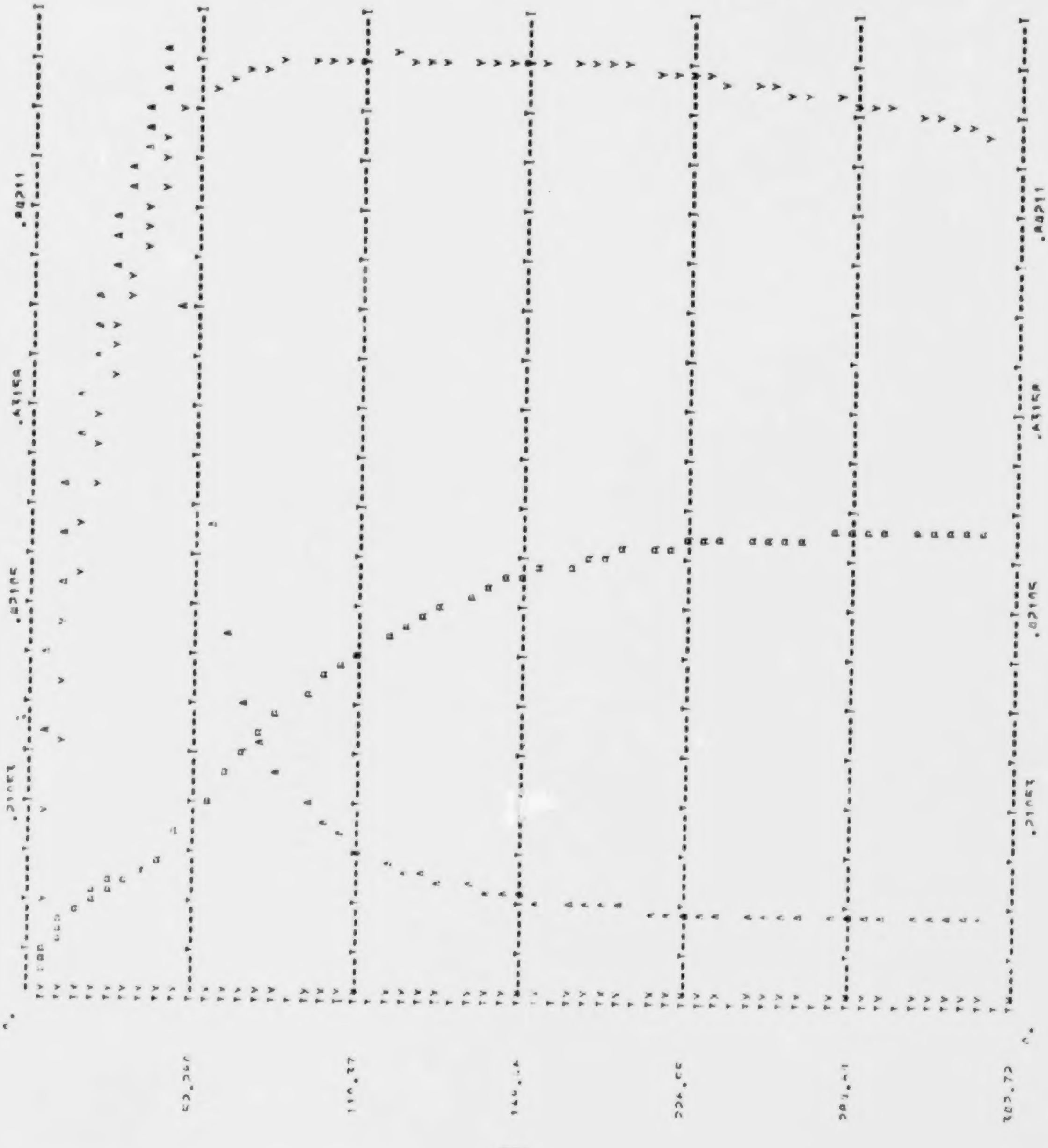
RUN D-L-4

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                0.                 47.678301
RANGE OF CONCENTRATIONS PLOTTED           0.                 .80000000
```



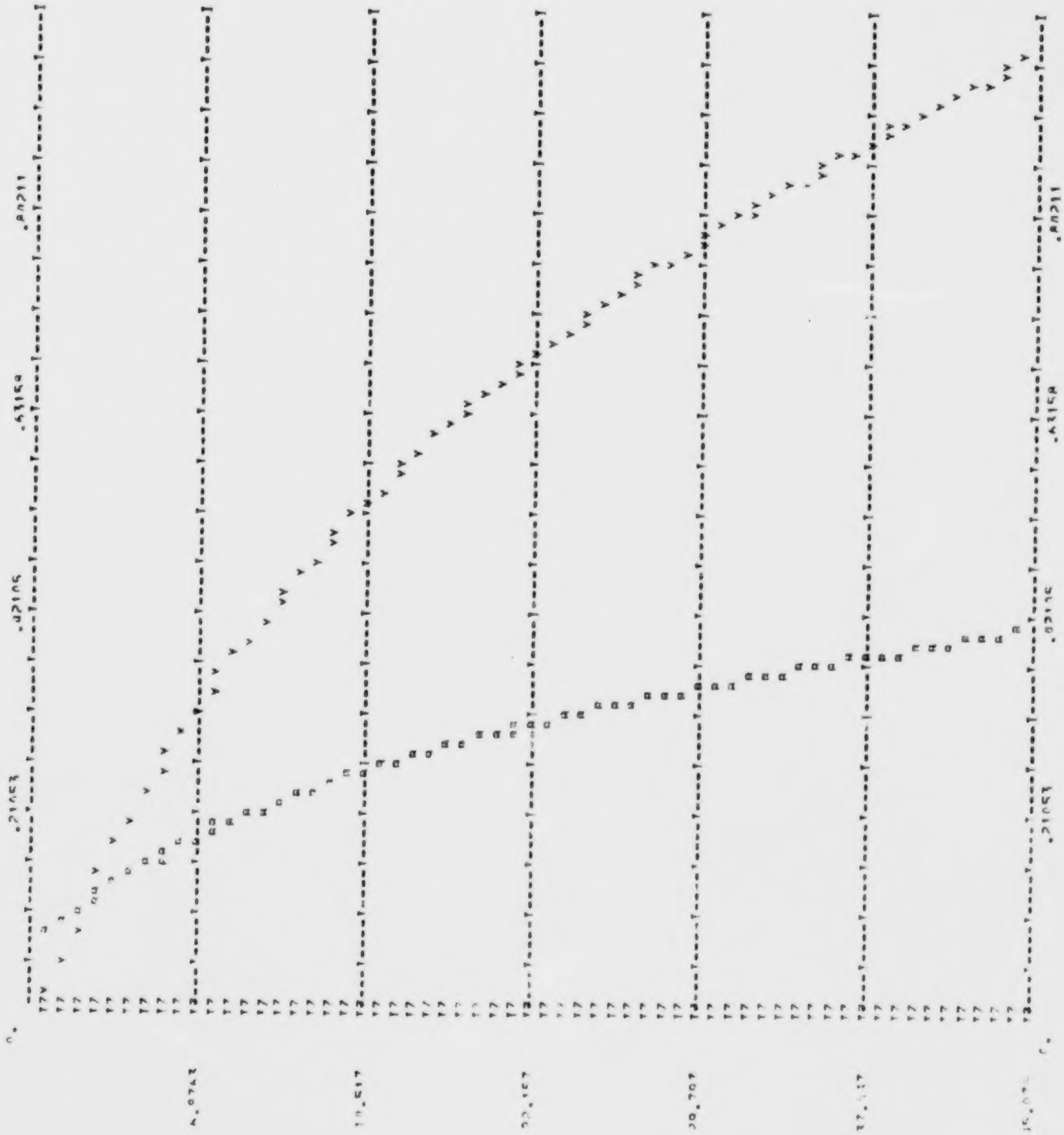
RUN D-L-4

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          342.72

                    DEPENDENT VARIABLES

SYMBOL                A            B           X            Y
MAX PLOTTED      13.006       90.680      0.          98.668
MIN PLOTTED      0.           0.          0.          0.
REMARKS          VERT. SIZE.  HOR. SIZE   HOR. DIST.  VERT. DIST.
```



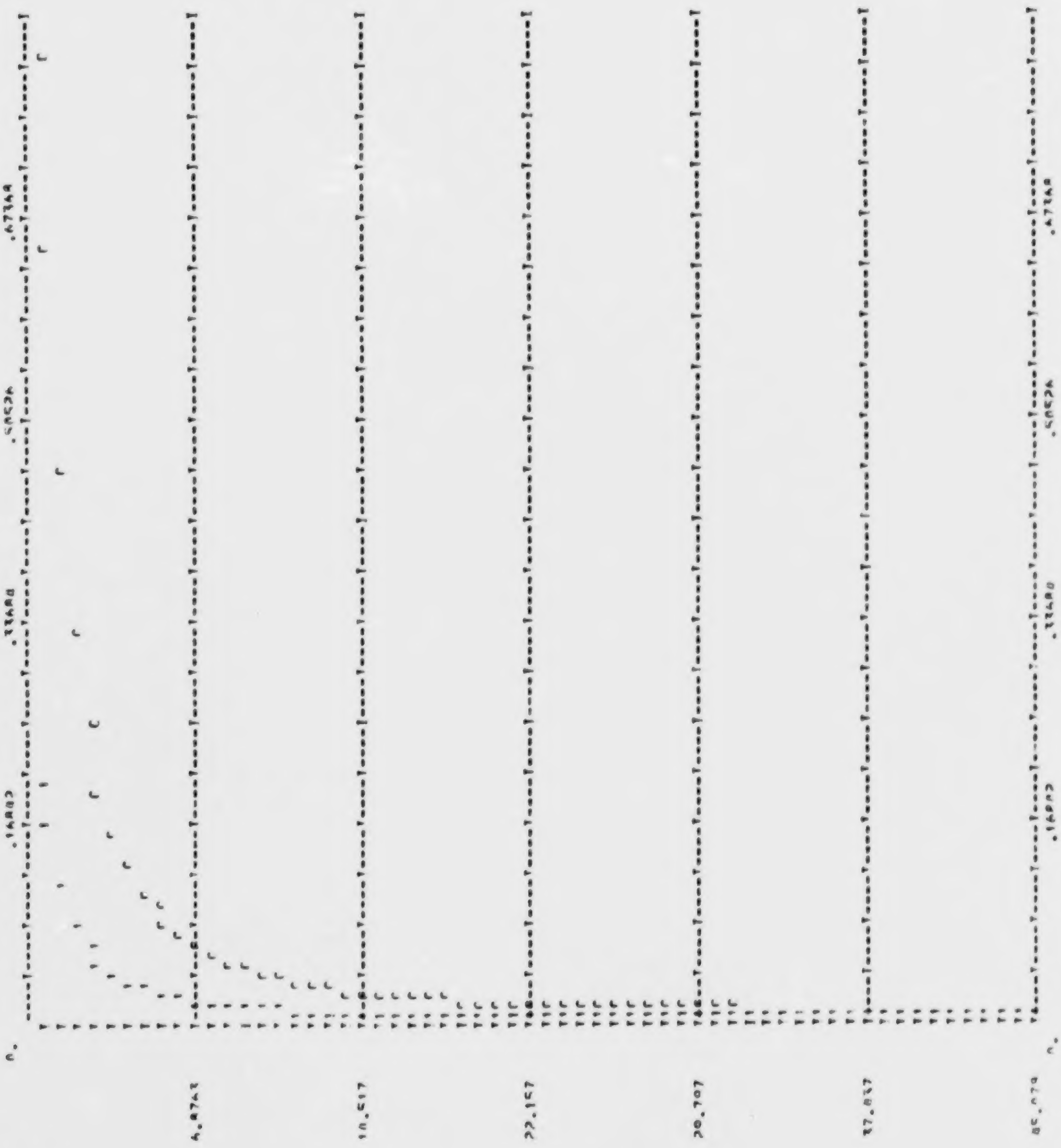
RUN D-L-5

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           45.078

                    DEPENDENT VARIABLES

SYMBOL               V              R              X              Z
MAX PLOTTED      90.325         24.226          0.             0.
MIN PLOTTED     0.             0.              0.             0.
REMARKS         VERT. DIST.     RADIUS        HOR. DIST.    HOR. DIST.
```



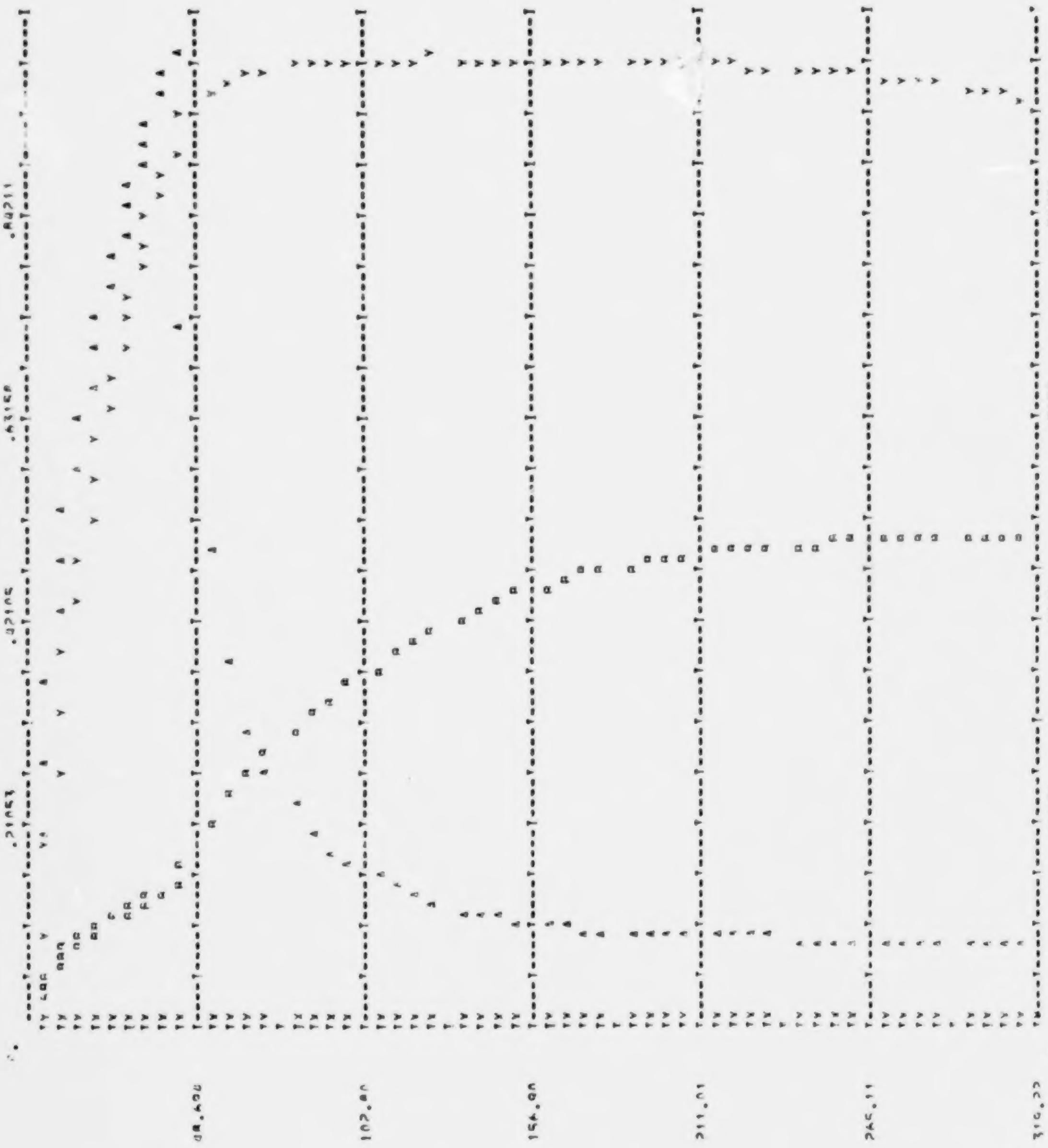
RUN D-L-5

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                             0.                    85.077704
RANGE OF CONCENTRATIONS PLOTTED        0.                    .80000000
```



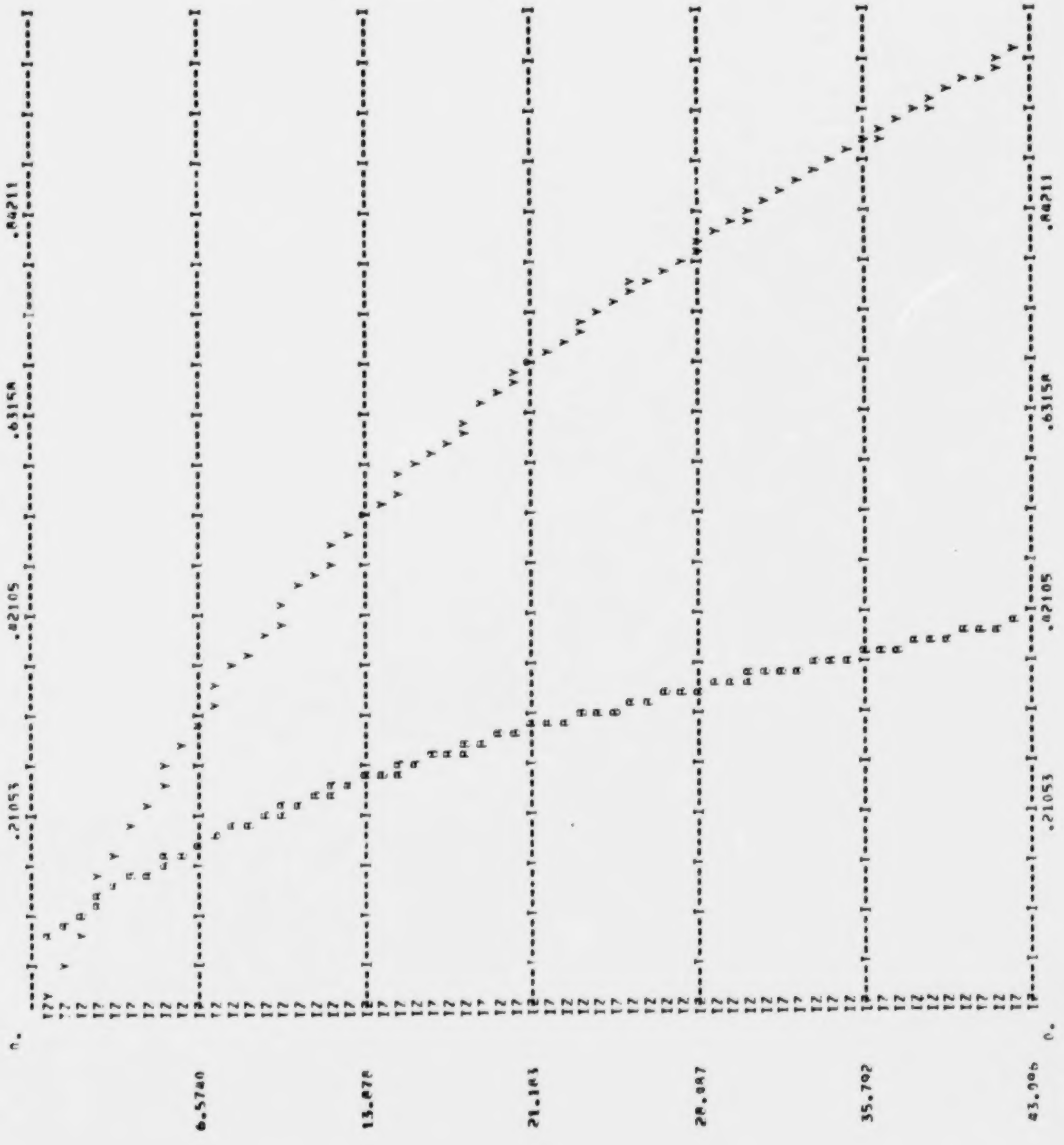
RUN D-L-5

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          319.22

                      DEPENDENT VARIABLES

SYMBOL                A              B              Y              V
MAX PLOTTED        13.000         93.579         0.             98.921
MIN PLOTTED       0.             0.             0.             0.
REMARKS           VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



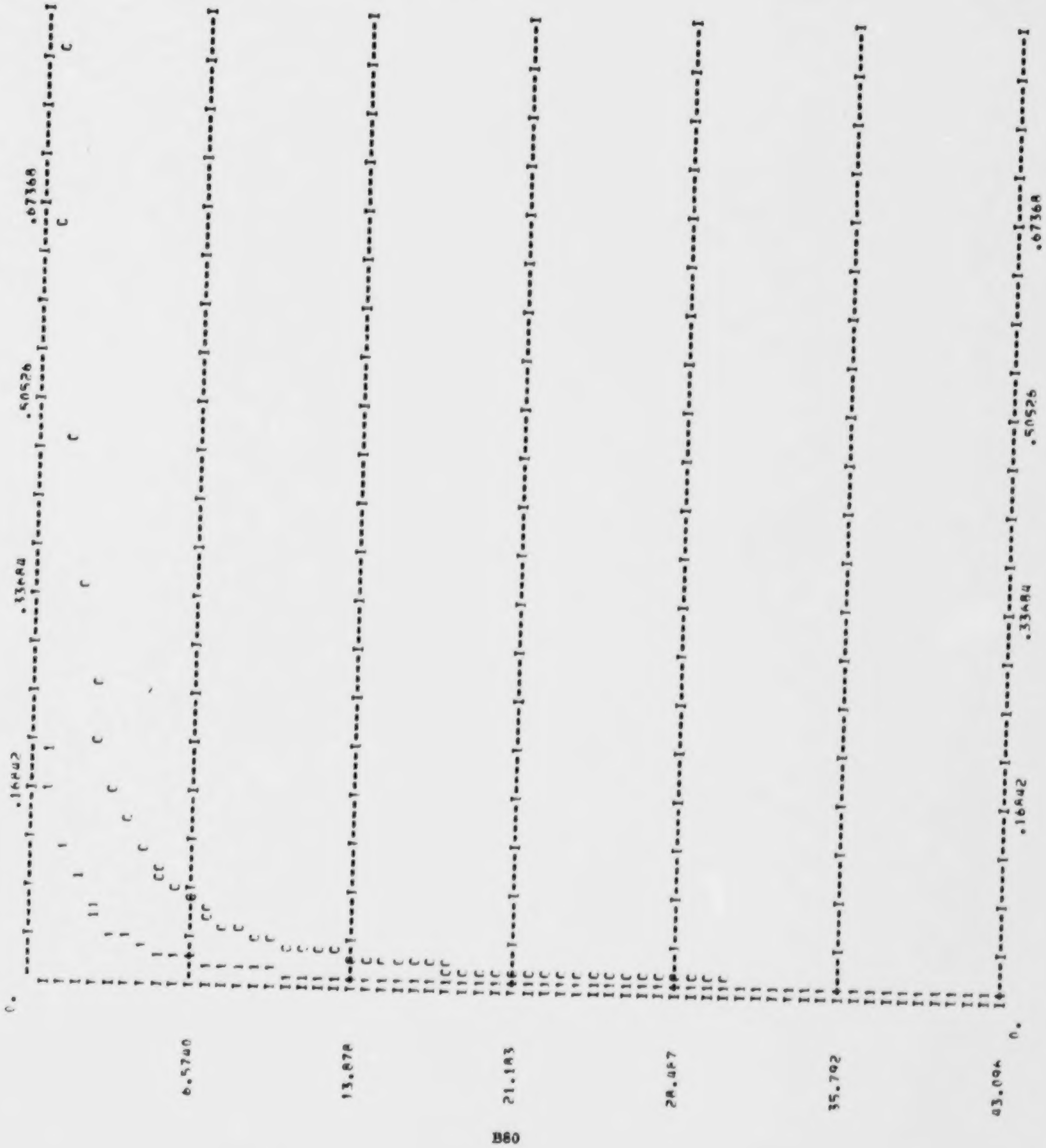
RUN D-L-6

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           43.096

                    DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED      90.352         26.232         0.             0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



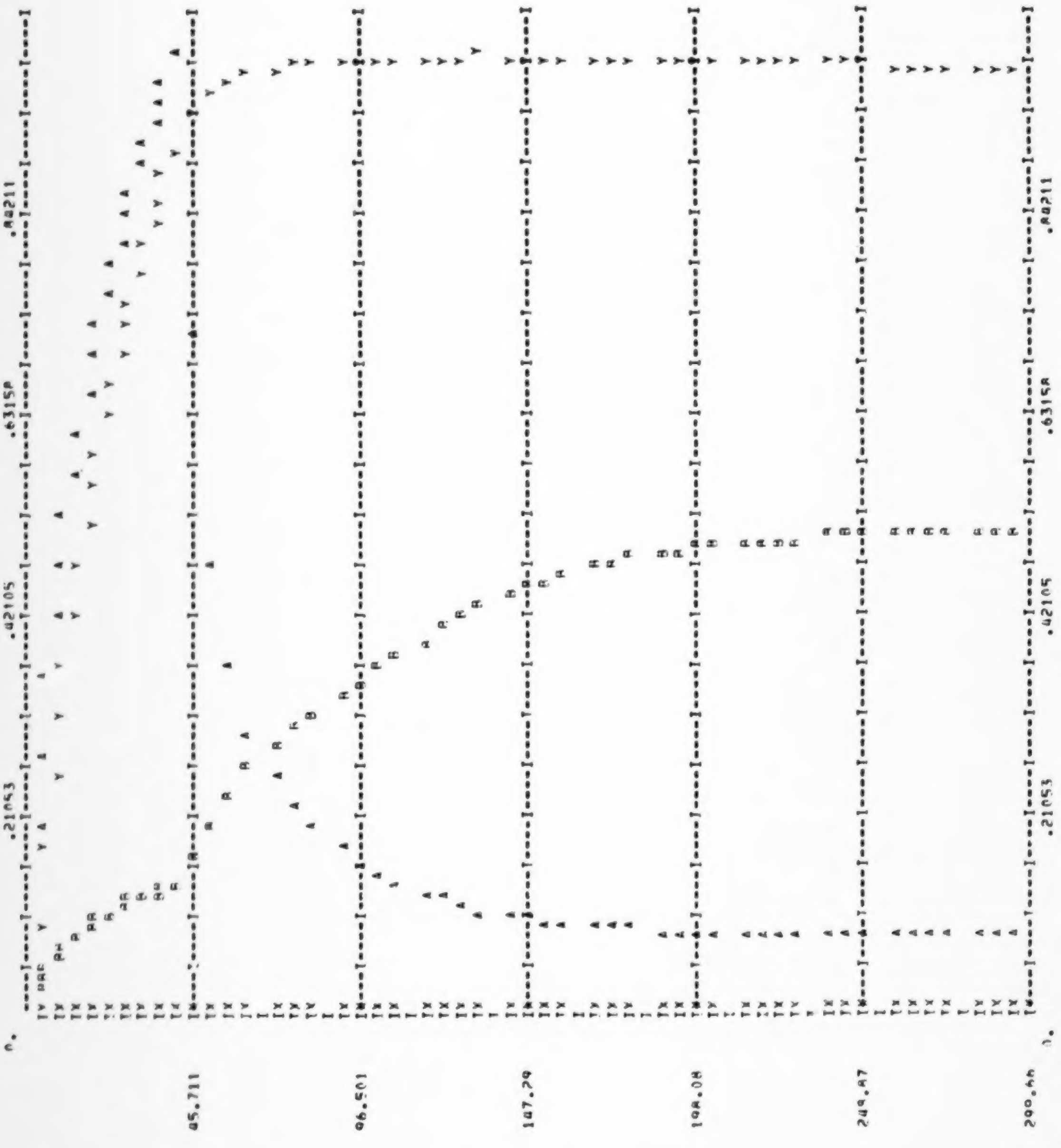
RUN D-L-6

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                0.                    43.096266
RANGE OF CONCENTRATIONS PLOTTED           0.                    .80000000
```



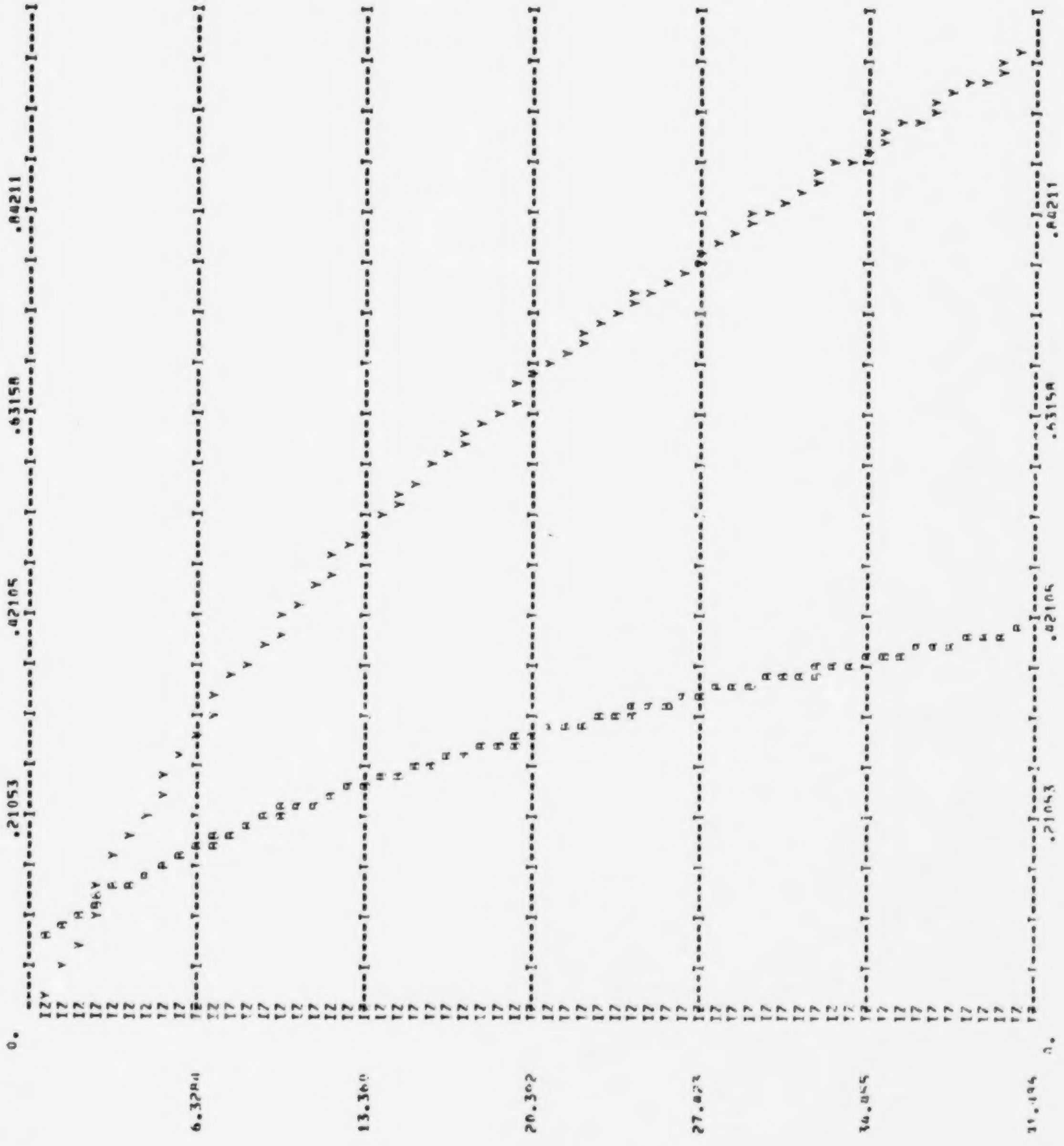
RUN D-L-6

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          299.66

                        DEPENDENT VARIABLES

SYMBOL             A             B            X              Y
MAX PLOTTED     12.997        96.515        0.            99.138
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. SIZE.   HOR. SIZE     HOR. DIST.    VERT. DIST.
```



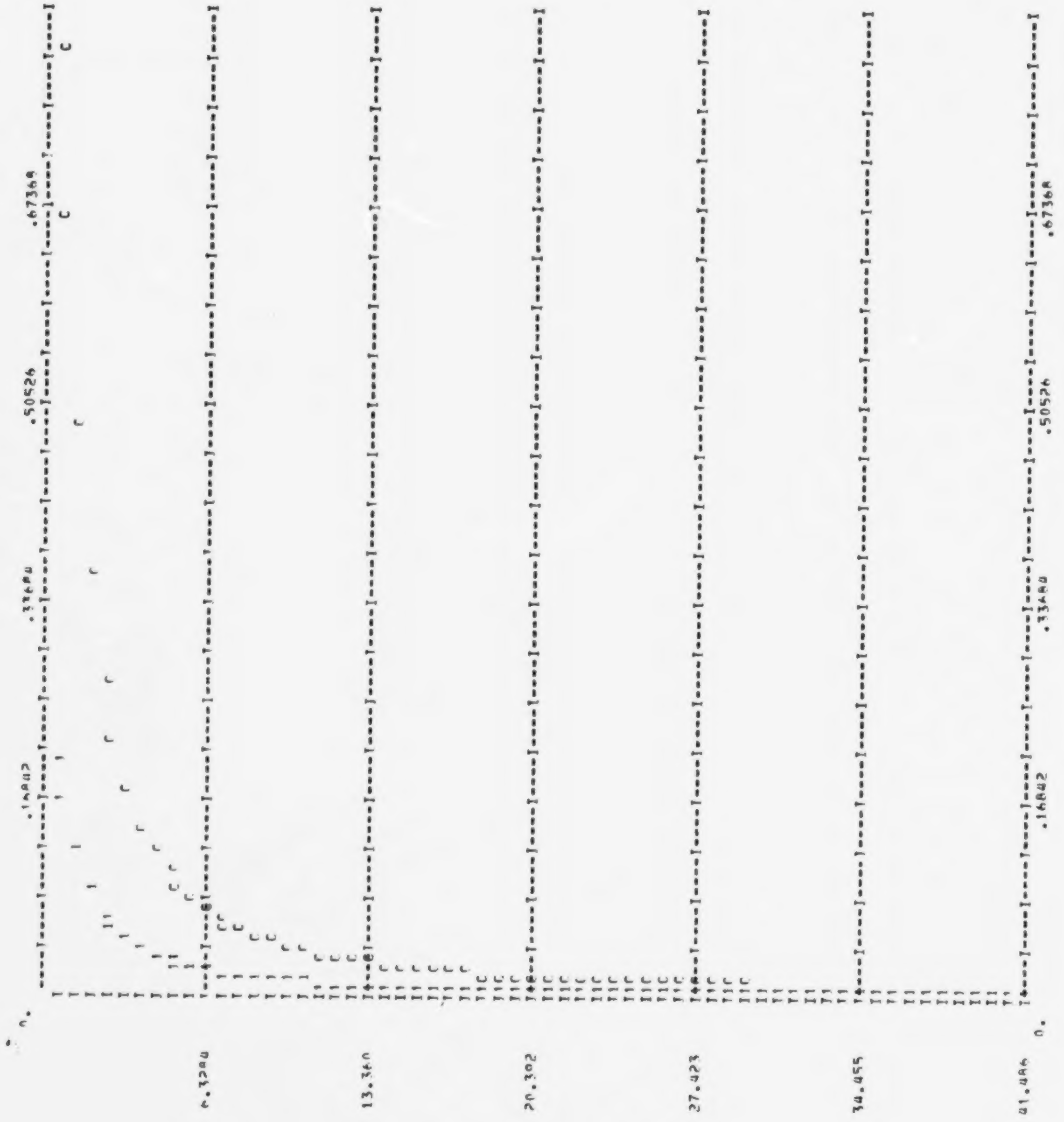
RUN D-L-7

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          41.486

                        DEPENDENT VARIABLES

SYMBOL               Y              R              X              Z
MAX PLOTTED     90.354         26.233         0.             0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



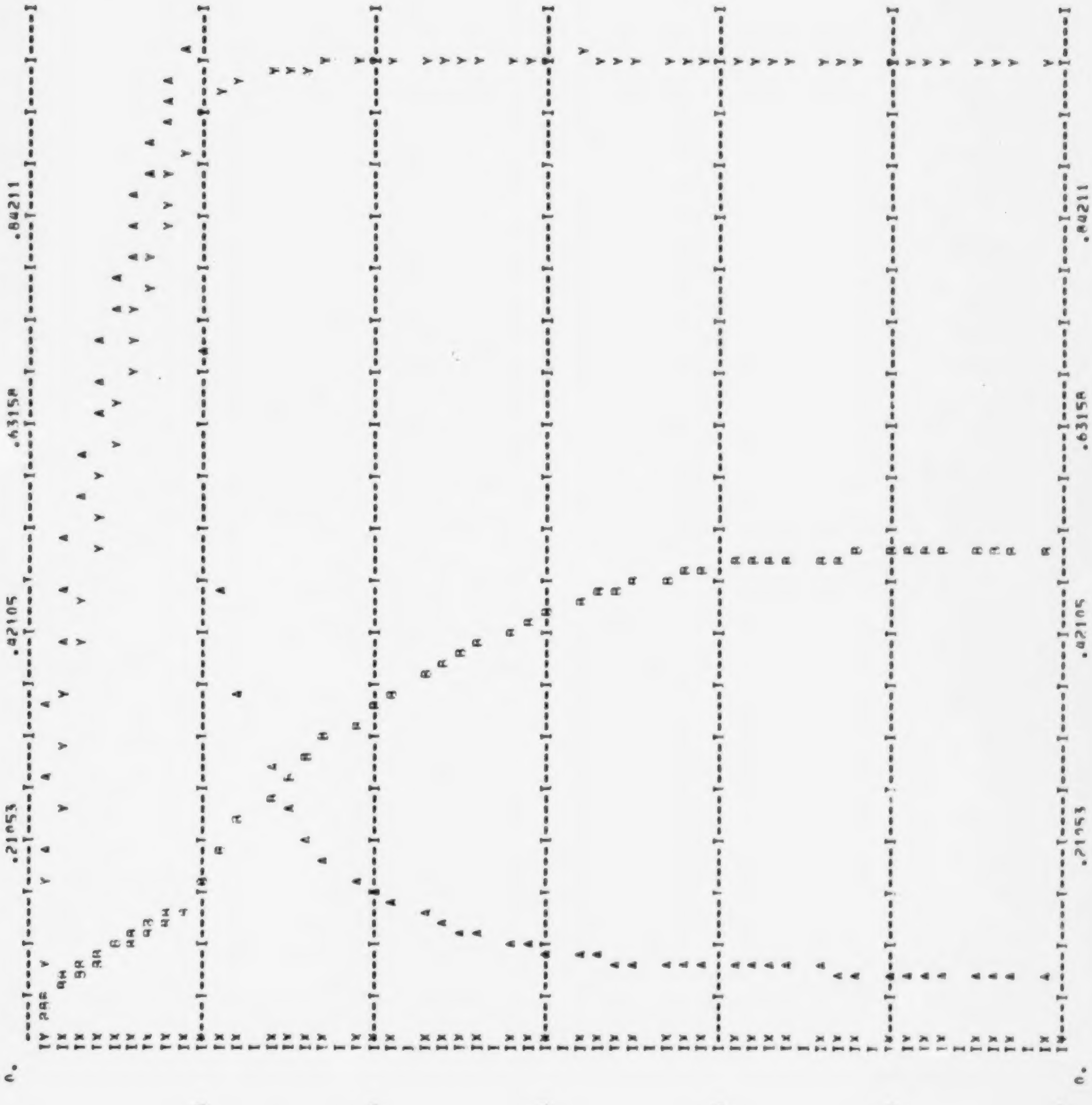
RUN D-L-7

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                    0.                     41.486348
RANGE OF CONCENTRATIONS PLOTTED               0.                     .80000000
```



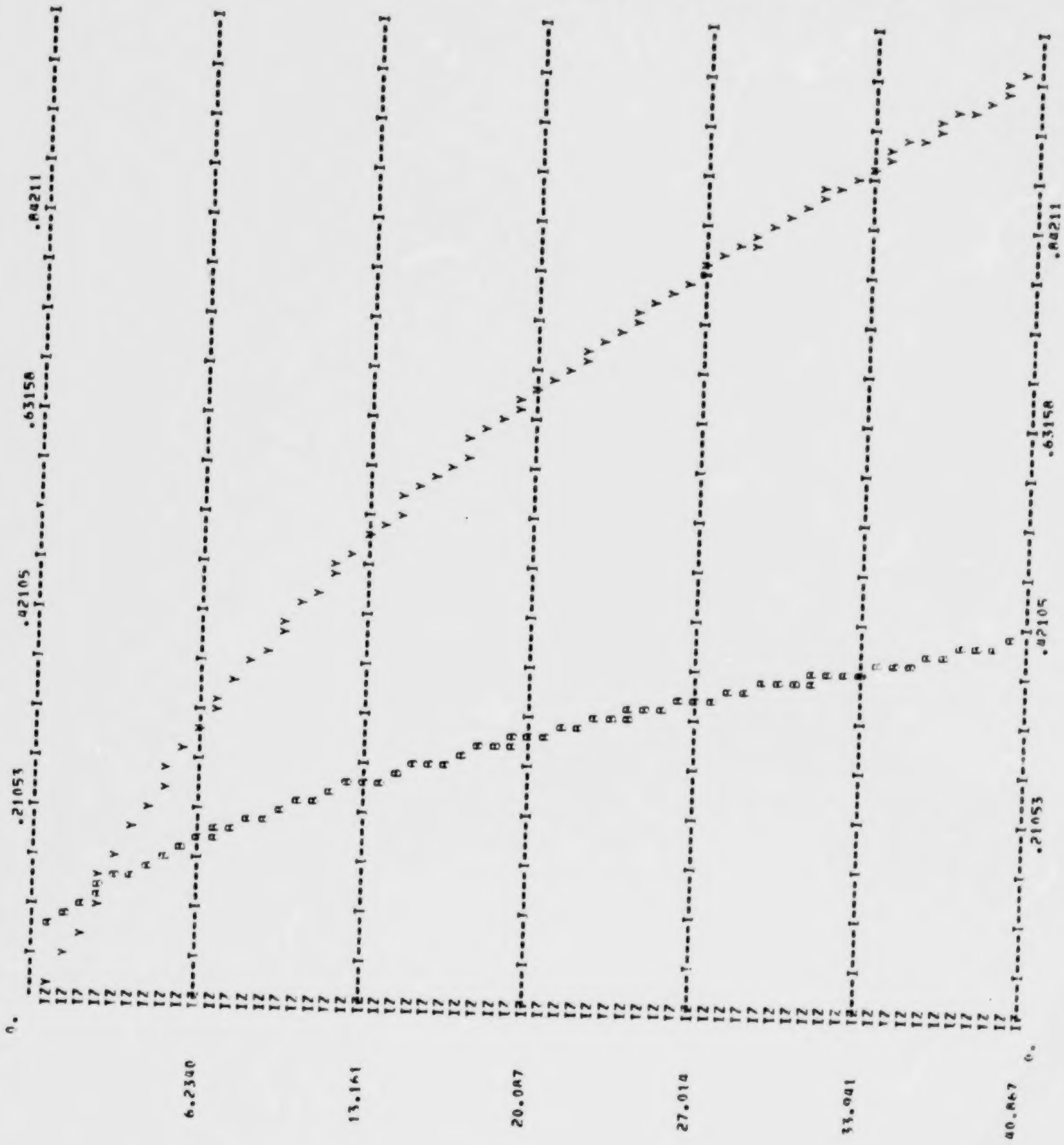
RUN D-L-7

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          284.92

                    DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED      12.992         99.985         0.             92.303
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



RUN D-L-8

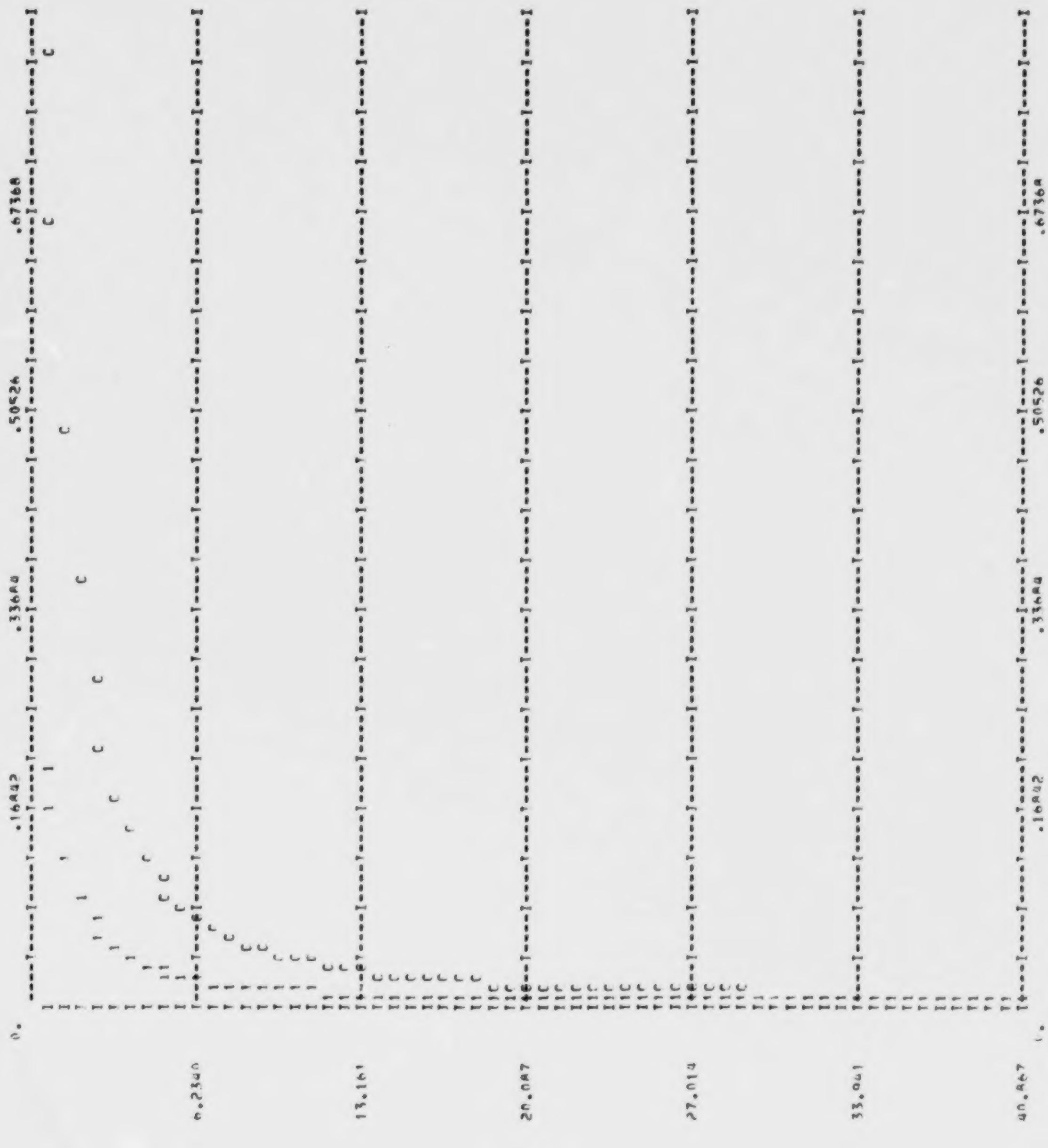
```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          40.867

                         DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED      90.457         26.257         0.             0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



RUN D-L-8

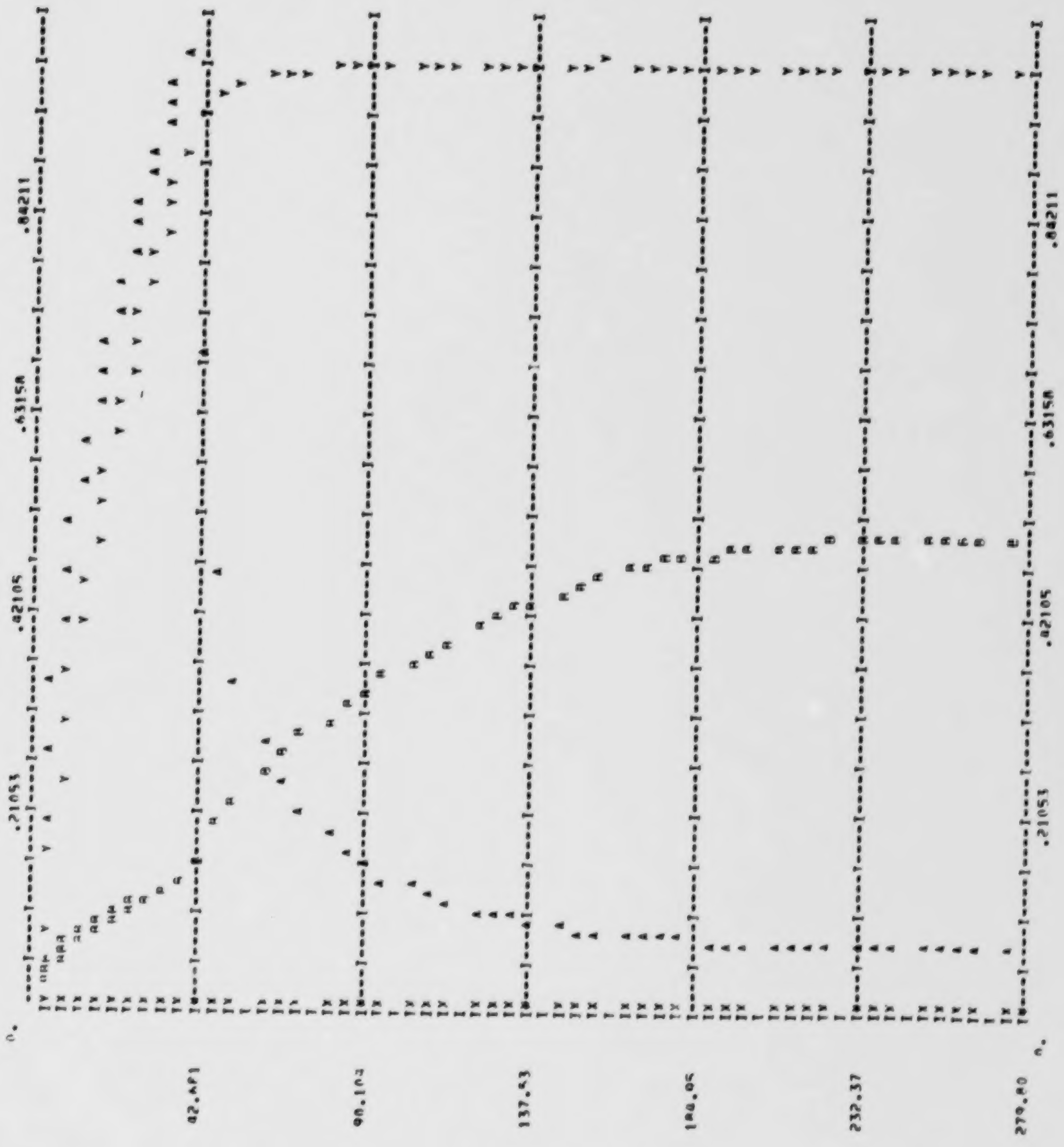
GRAPH OF WASTE CONCENTRATIONS

RANGE OF X 0. 40.867149
RANGE OF CONCENTRATIONS PLOTTED 0. .80000000



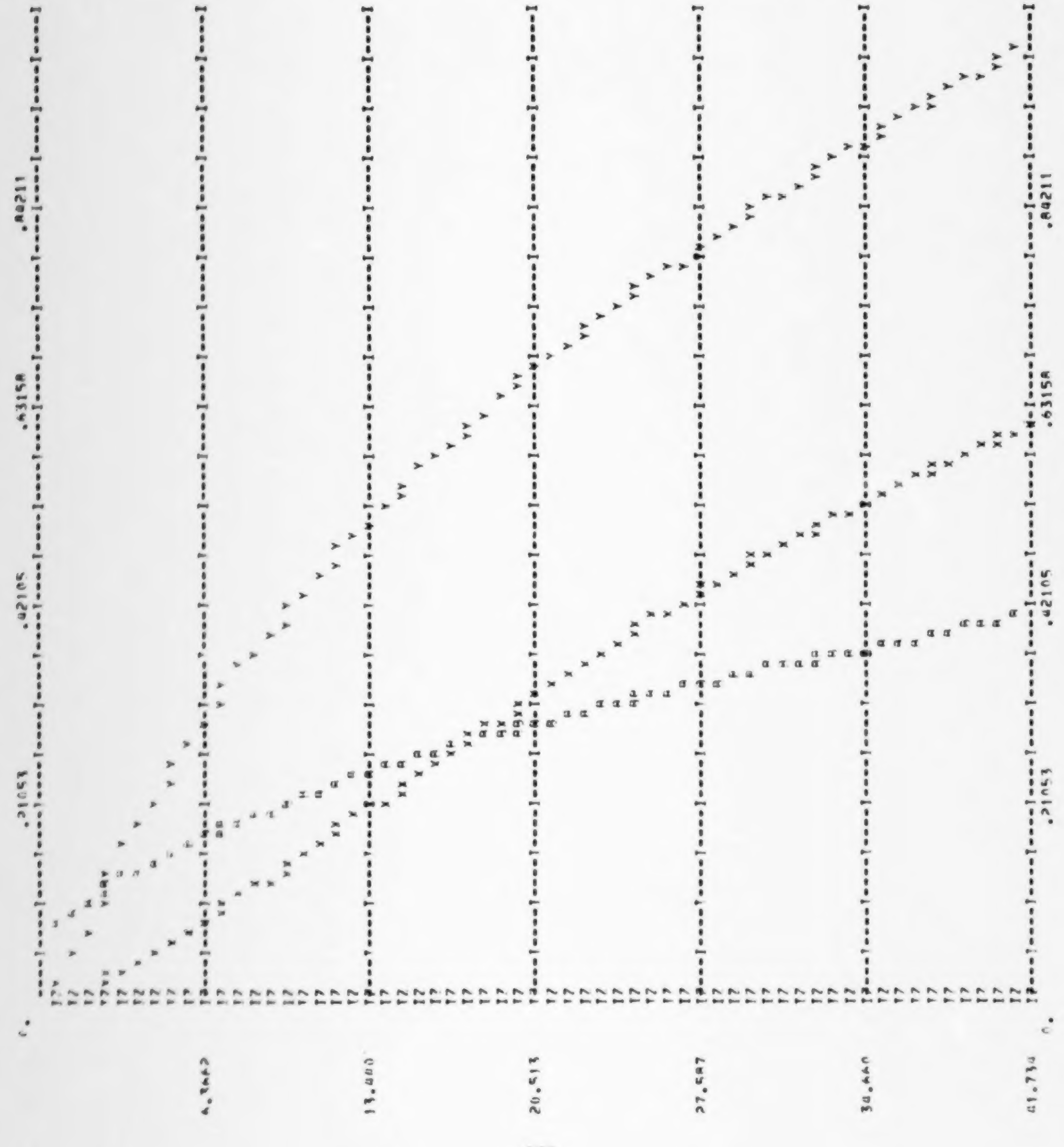
RUN D-L-8

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          279.80

                       DEPENDENT VARIABLES

SYMBOL                 A            B             X              Y
MAX PLOTTED       13.002        102.22        0.             99.493
MIN PLOTTED       0.            0.            0.             0.
REMARKS           VERT. SIZE.   HOR. SIZE     HOR. DIST.    VERT. DIST.
```



RUN D-L-9

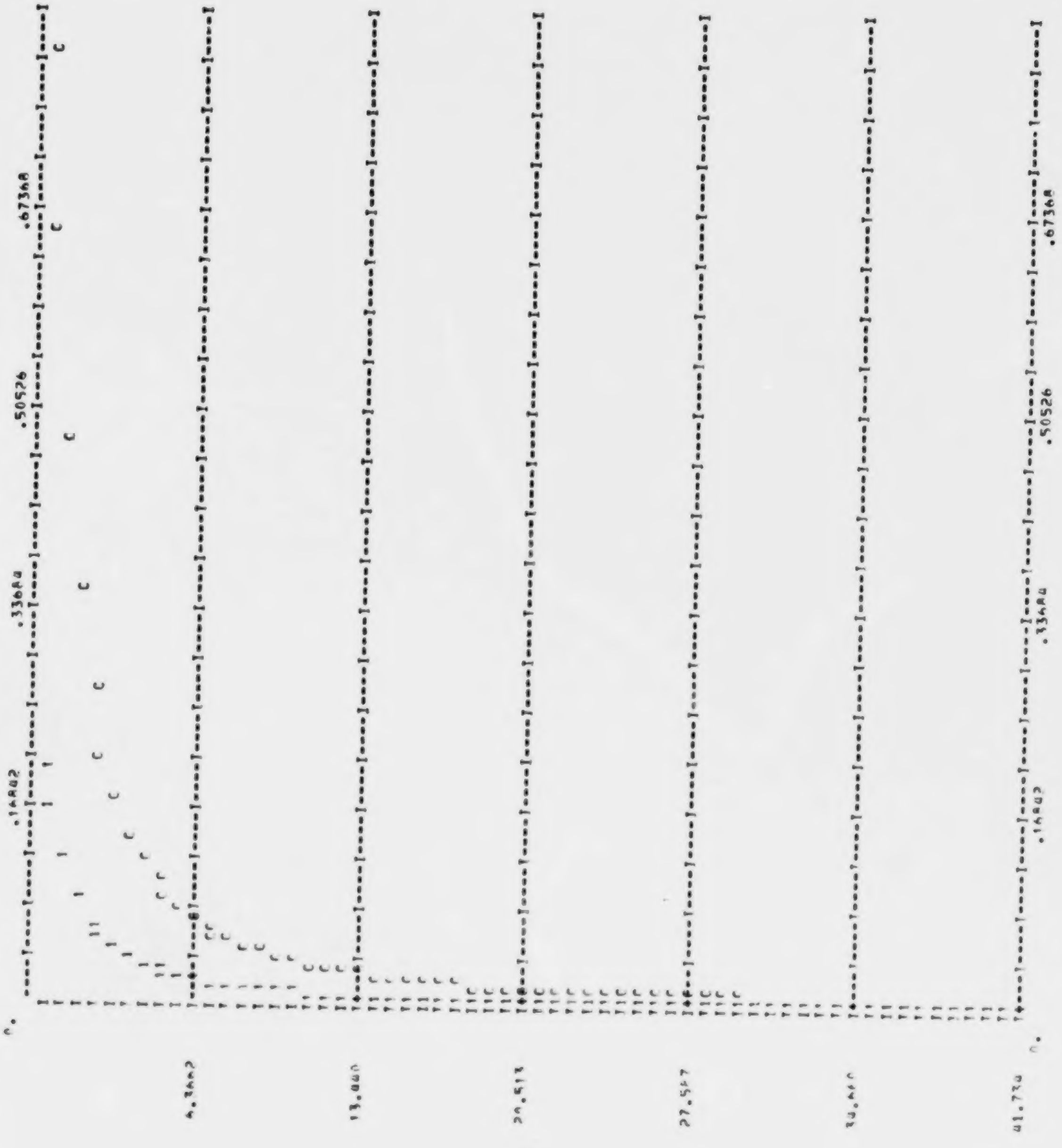
```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           41.734

                    DEPENDENT VARIABLES

SYMBOL               Y              R              X              Z
MAX PLOTTED       90.296         26.424         34.777         0.
MIN PLOTTED       0.             0.             0.             0.
REMARKS           VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



RUN D-L-9

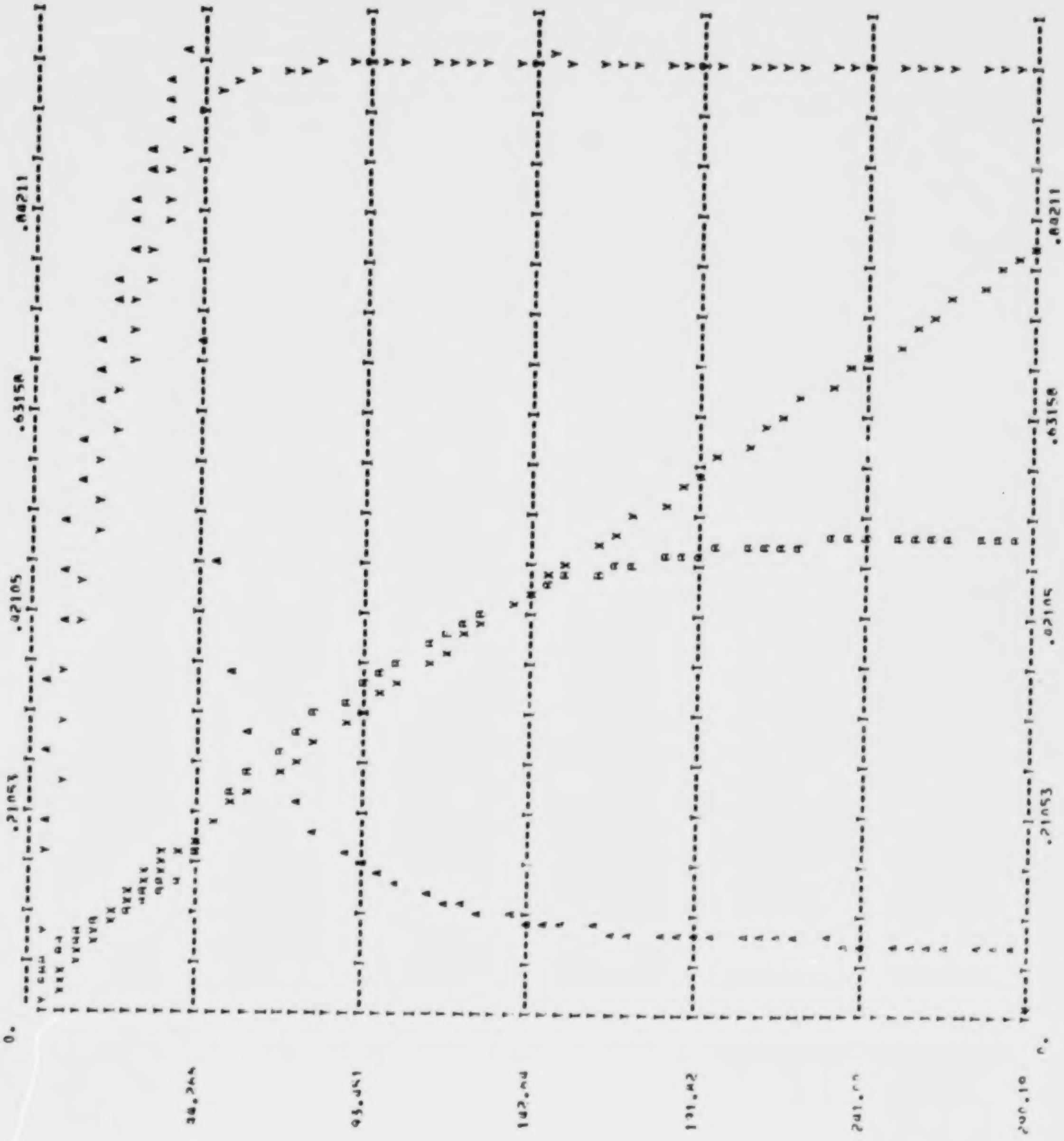
GRAPH OF WASTE CONCENTRATIONS

RANGE OF X 0. 41.734028
RANGE OF CONCENTRATIONS PLOTTED 0. .80000000



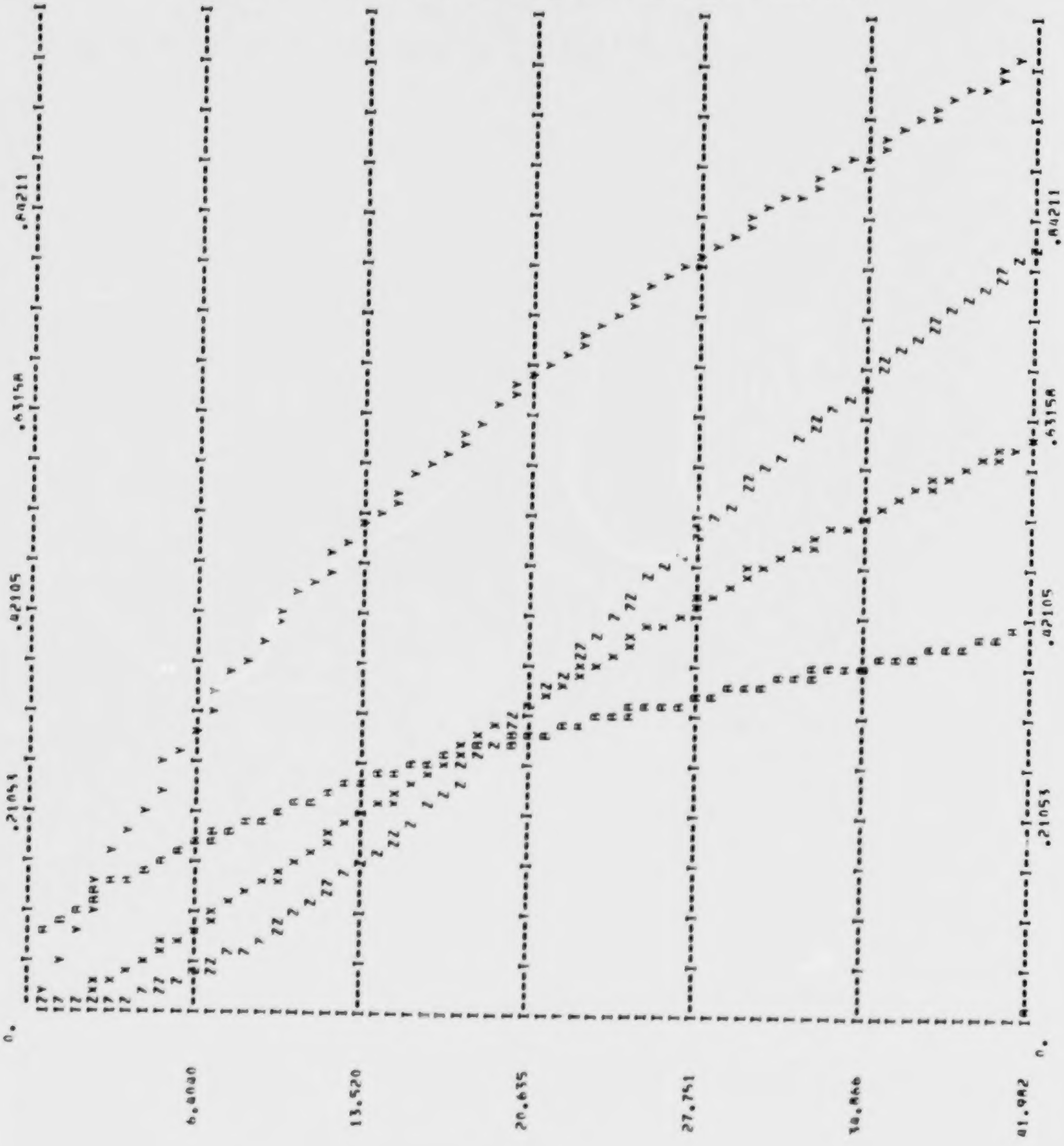
RUN D-L-9

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          290.19

                    DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED      13.083         100.35         165.96         99.301
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```

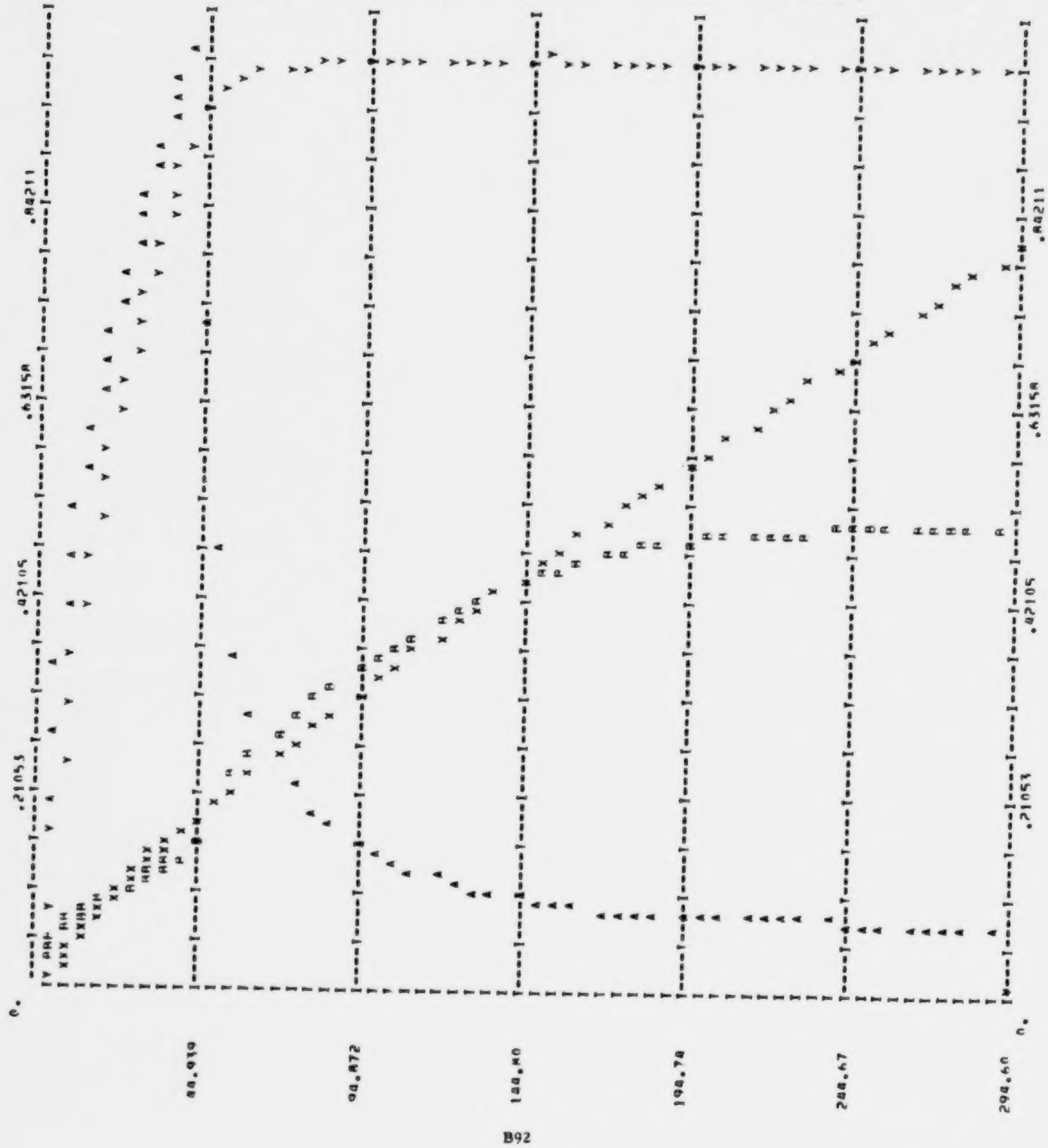


RUN D-L-10

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           41.982

                    DEPENDENT VARIABLES

SYMBOL              Y           R           X           Z
MAX PLOTTED     90.361      26.576      34.988      24.012
MIN PLOTTED     0.          0.          0.          0.
REMARKS         VERT. DIST.   RADIUS    HOR. DIST.  HOR. DIST.
```

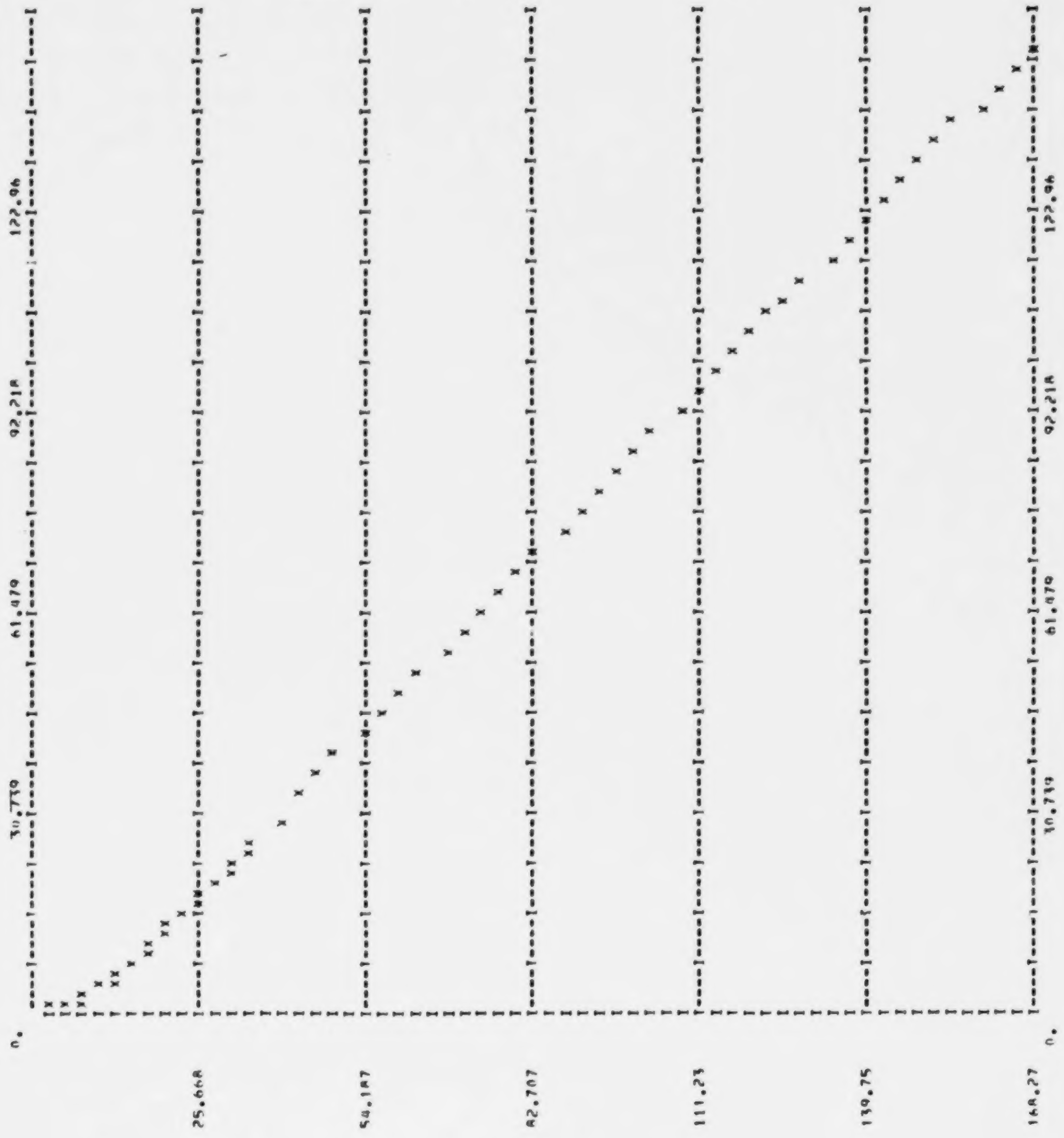


```
                              RUN D-L-10
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          294.60

                         DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     13.156         100.71         168.27         99.413
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



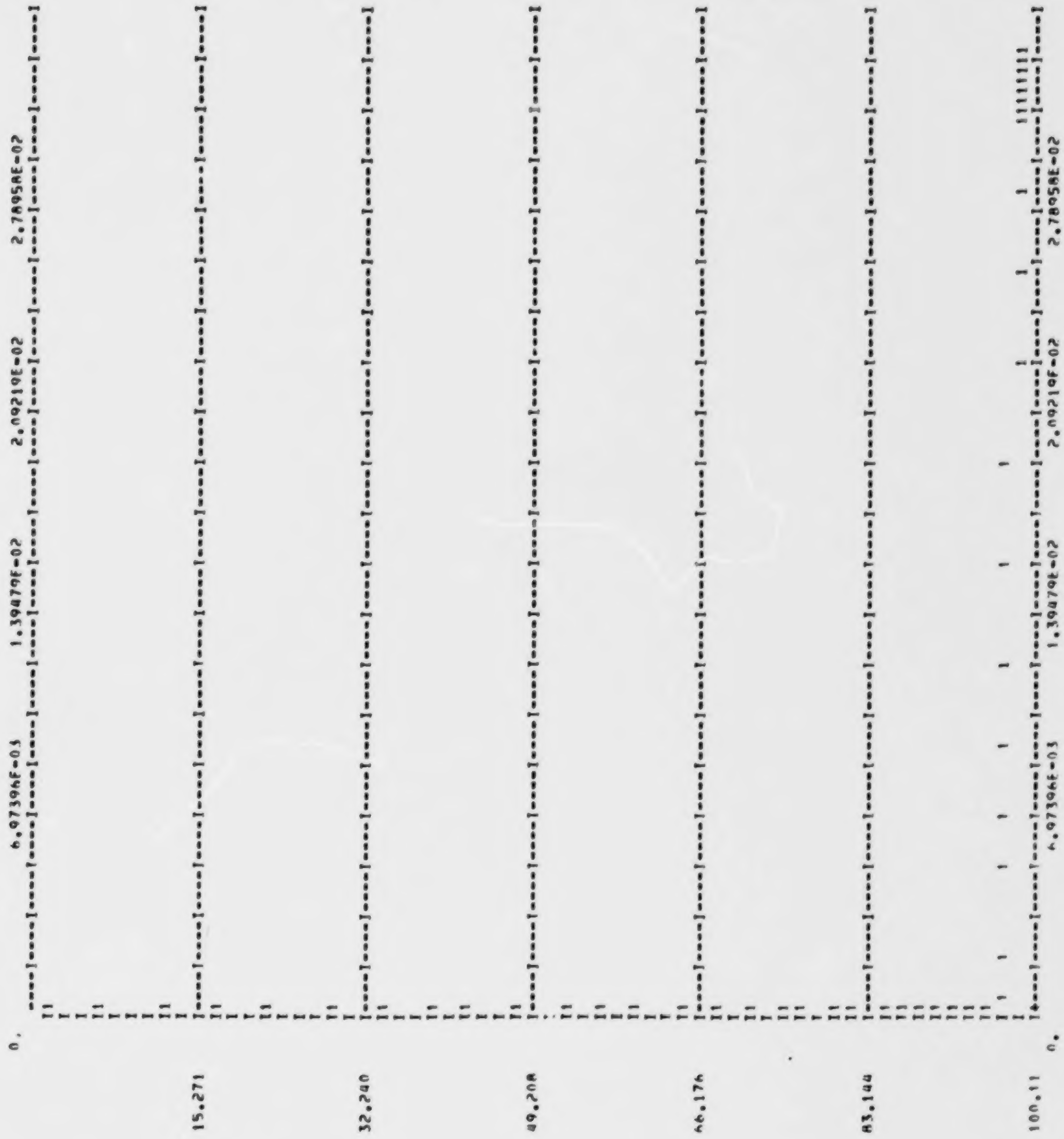
RUN D-L-10

```
GRAPH OF X VS Z

RANGE OF X        0.                    168.26521
RANGE OF Z        0.                    146.01223
```



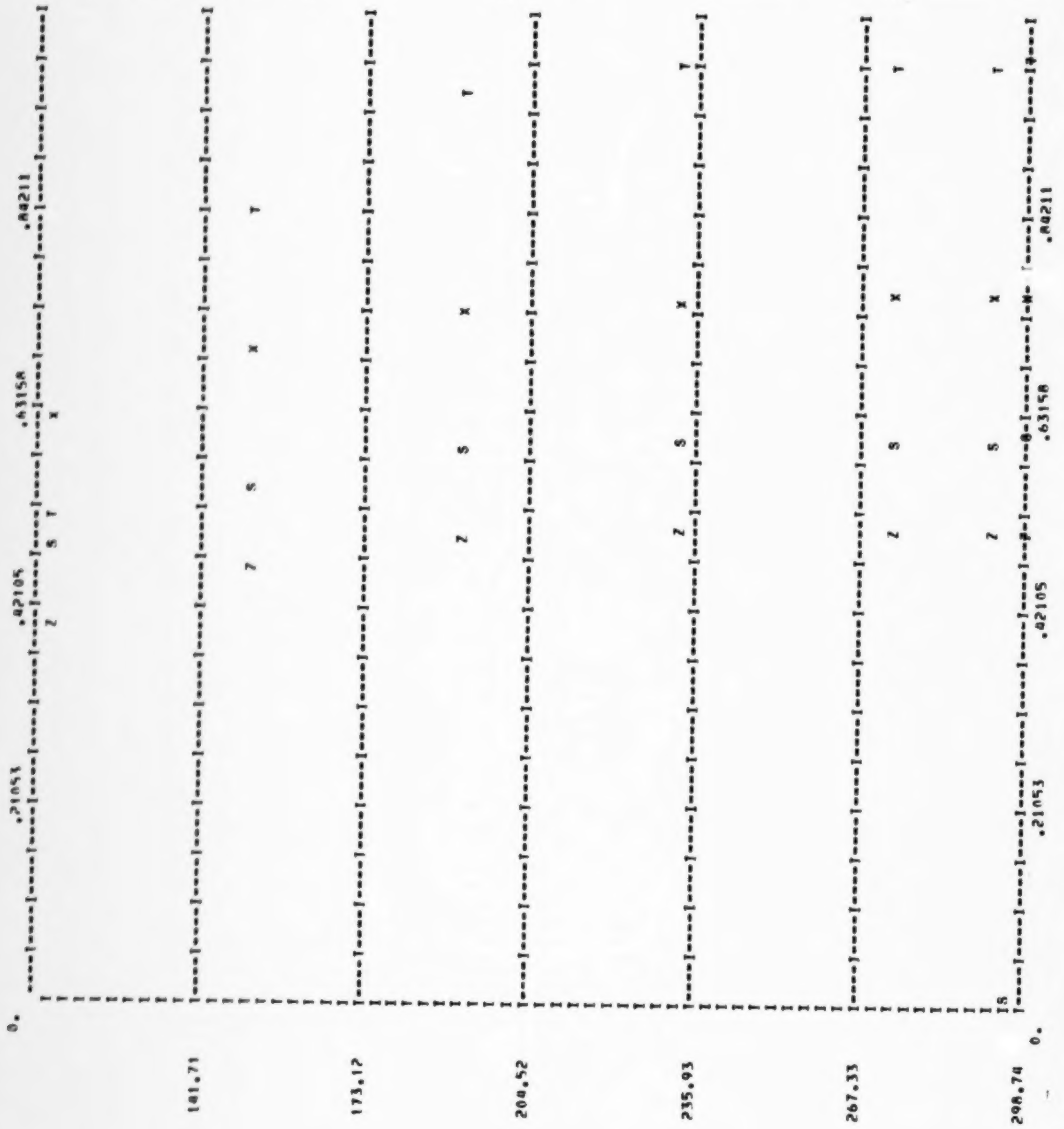
RUN D-L-10

```
                                GRAPH OF    COD   VS Y AT TIMES
298.74033              -1.0000000             -1.0000000            -1.0000000

      RANGE OF    Y    PLOTTED          0.                        100.11220
      RANGE OF   COD   PLOTTED          0.                        3.31263184E-02
```



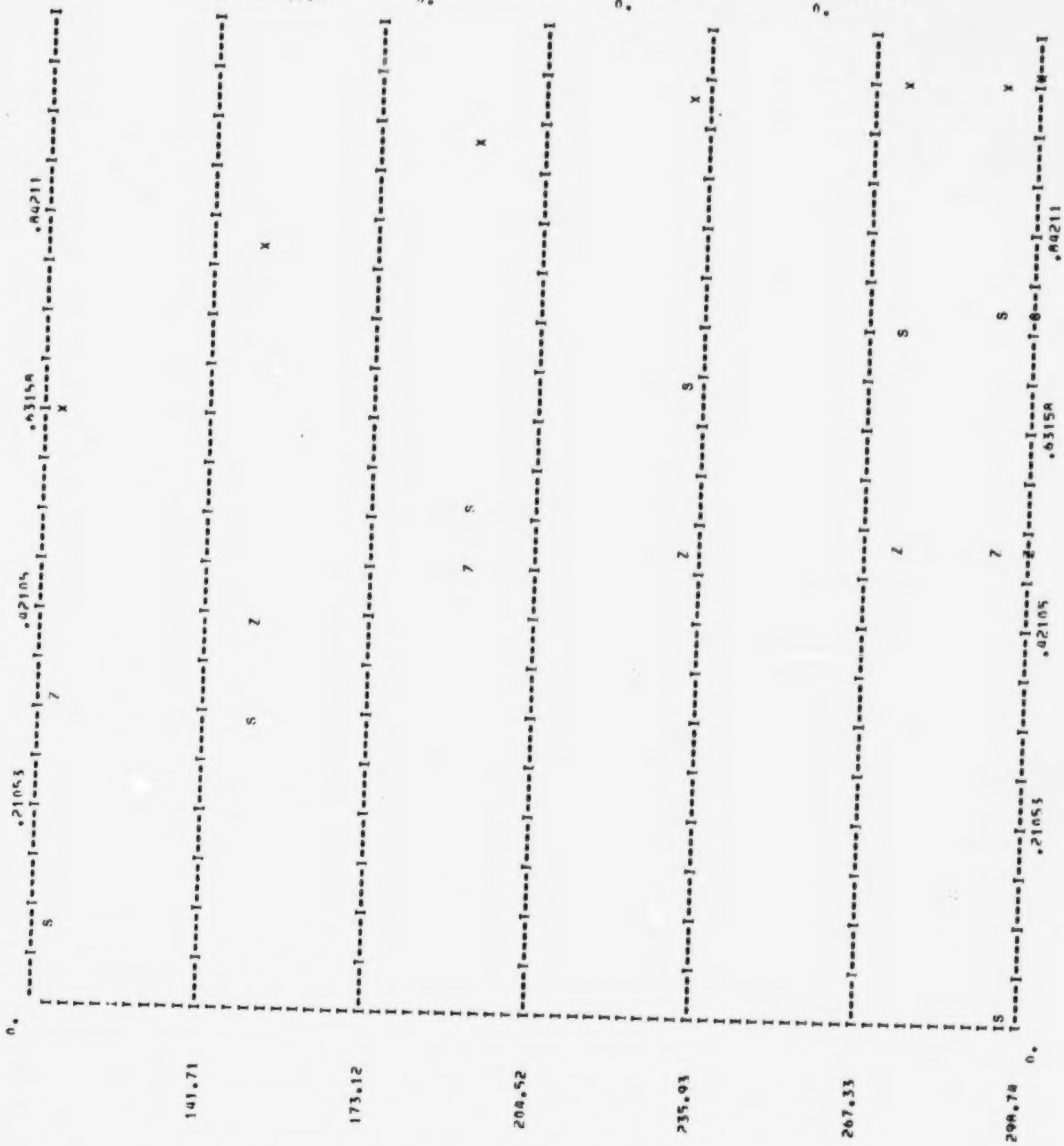
RUN D-L-10

```
PLOT OF TOT HDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE              113.44772            298.74033
MAXIMUM T,X,Z,S         52.301128            78.561629            63.918081            84.603557
MINIMUM T,X,Z,S        0.                   0.                   0.                   0.
```



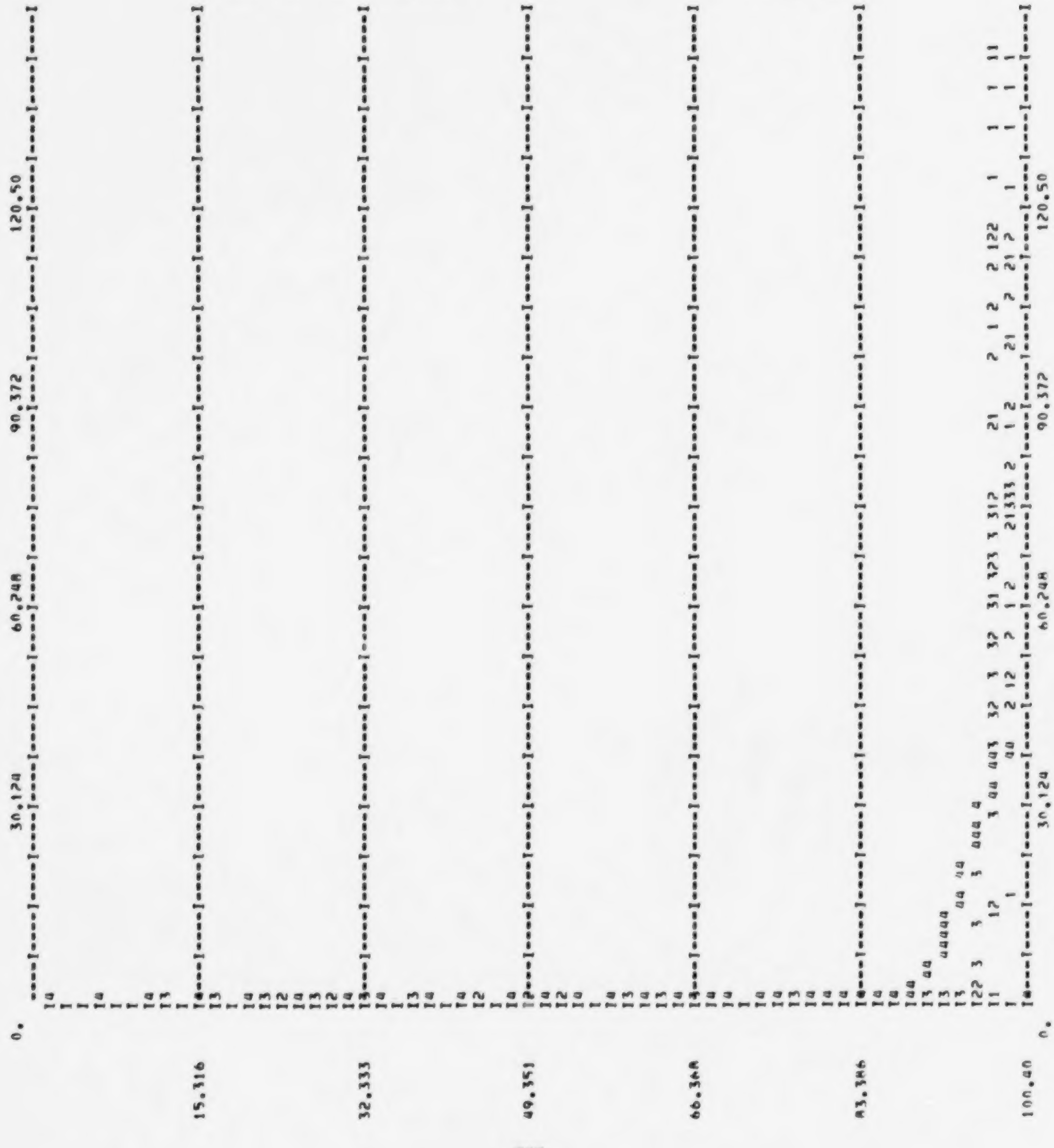
RUN D-L-10

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME
TIME RANGE=              113.40772              298.74033
MAXIMUM X,Z,S            1845.9728              1789.4582              318.10988
MINIMUM X,Z,S           0.                     0.                     0.
```



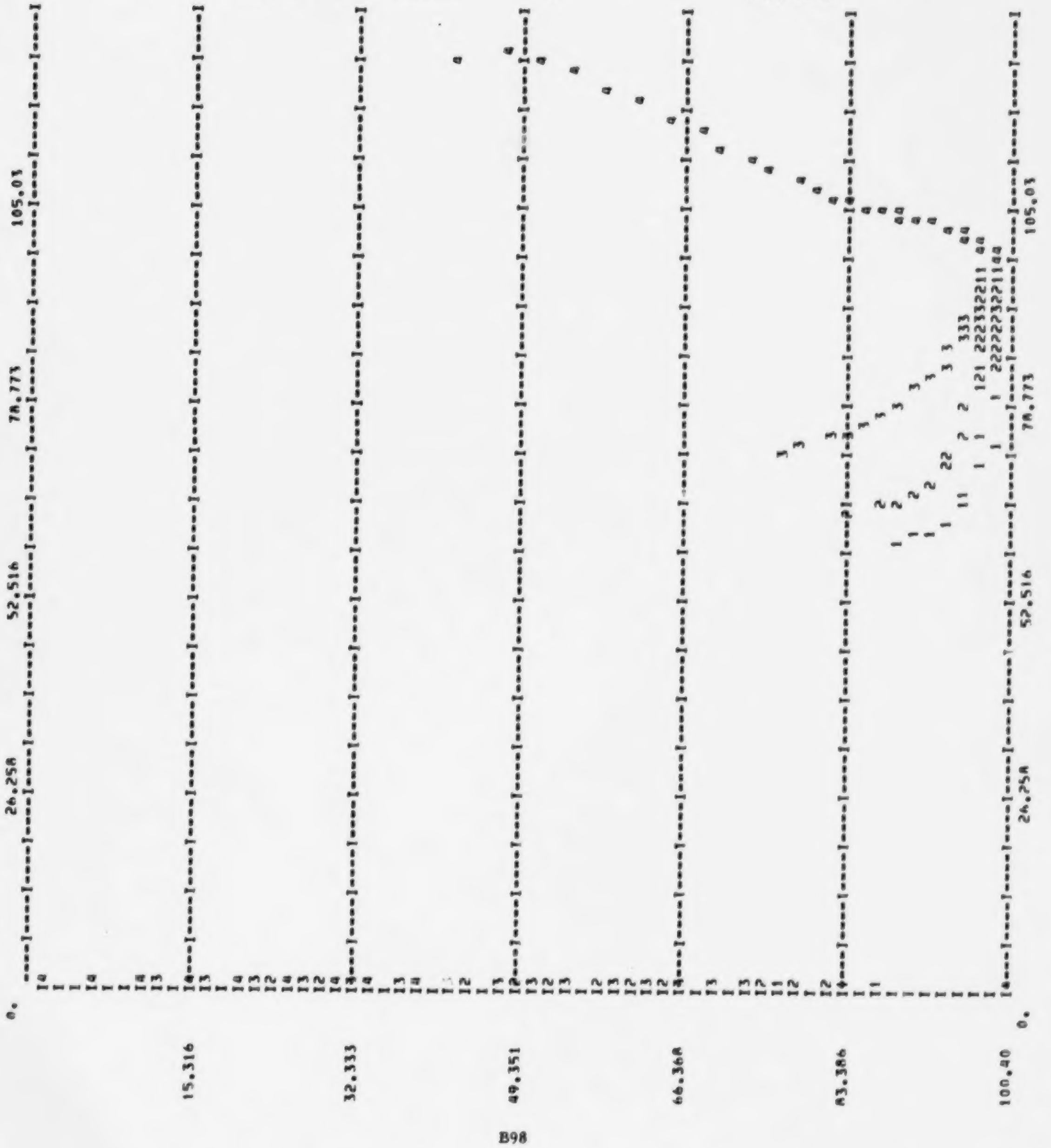
RUN D-L-10

```
                              GRAPH OF    COD   VS Y AT TIMES
   299.49454            308.86129             362.85903              1095.4773

       RANGE OF     Y    PLOTTED         0.                        100.40299
       RANGE OF   COD    PLOTTED         0.                        143.08834
```



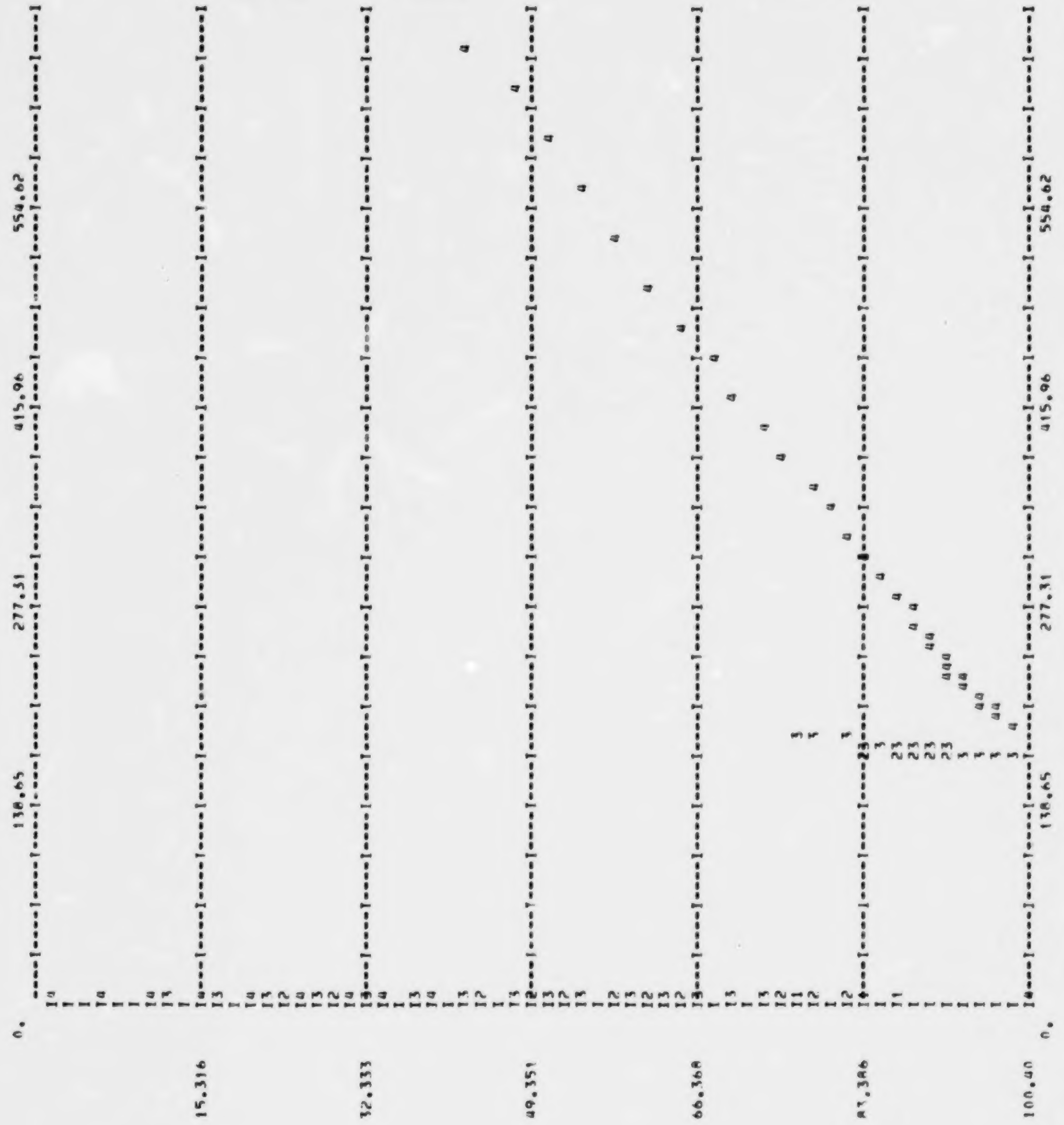
RUN D-L-10

```
                         GRAPH OF   SIZE  VS Y AT TIMES
299.49454               308.86129         362.85903              1095.4773
          RANGE OF    Y    PLOTTED        0.                     100.40299
          RANGE OF  SIZE   PLOTTED        0.                     124.72453
```



RUN D-L-10

```
                            GRAPH OF    XO   VS Y AT TIMES
299.49454              308.86129             362.85903           1095.4773

     RANGE OF    Y    PLOTTED        0.                         100.40299
     RANGE OF    XO   PLOTTED        0.                         658.60878
```



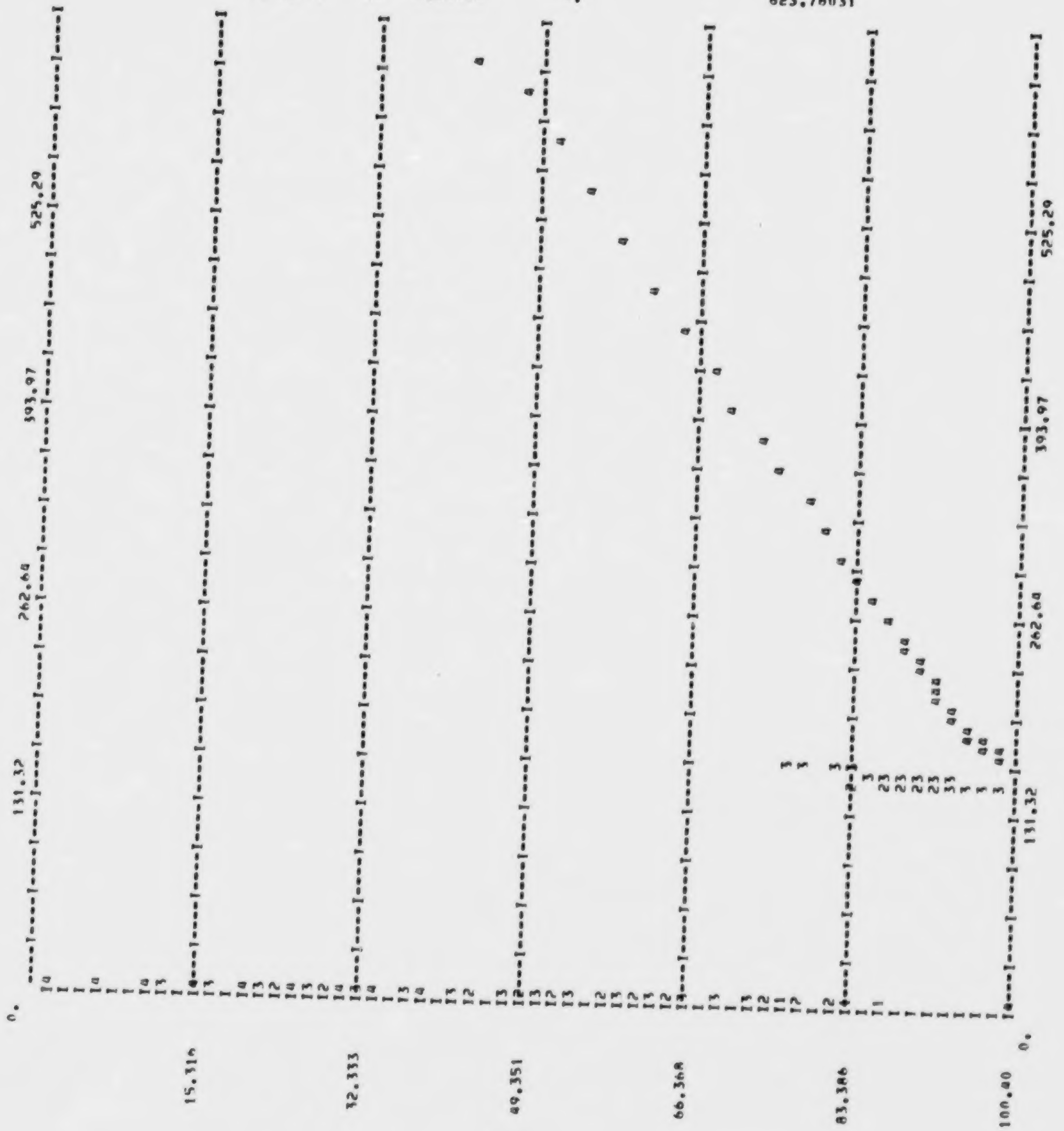
RUN D-L-10

GRAPH OF ZO VS Y AT TIMES

299.49454 308.86129 362.85903 1095.4773

RANGE OF Y PLOTTED 0. 100.40299

RANGE OF ZO PLOTTED 0. 623.78031

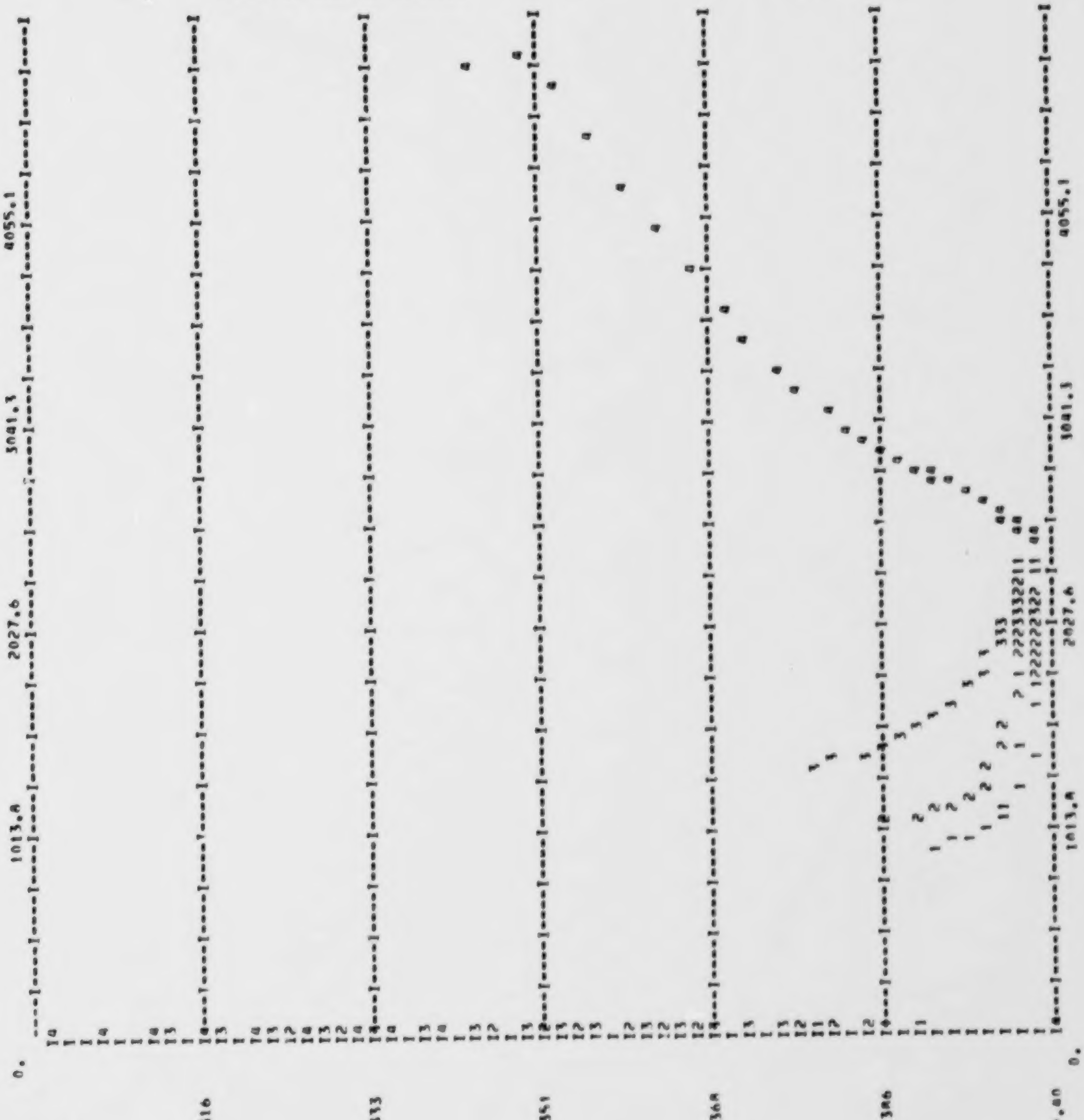


RUN D-L-10

GRAPH OF SIGMA-X VS Y AT TIMES

299.49454 308.86129 362.85903 1095.4773

RANGE OF Y PLOTTED 0. 100.40299
RANGE OF SIGMA-X PLOTTED 0. 4815.4704



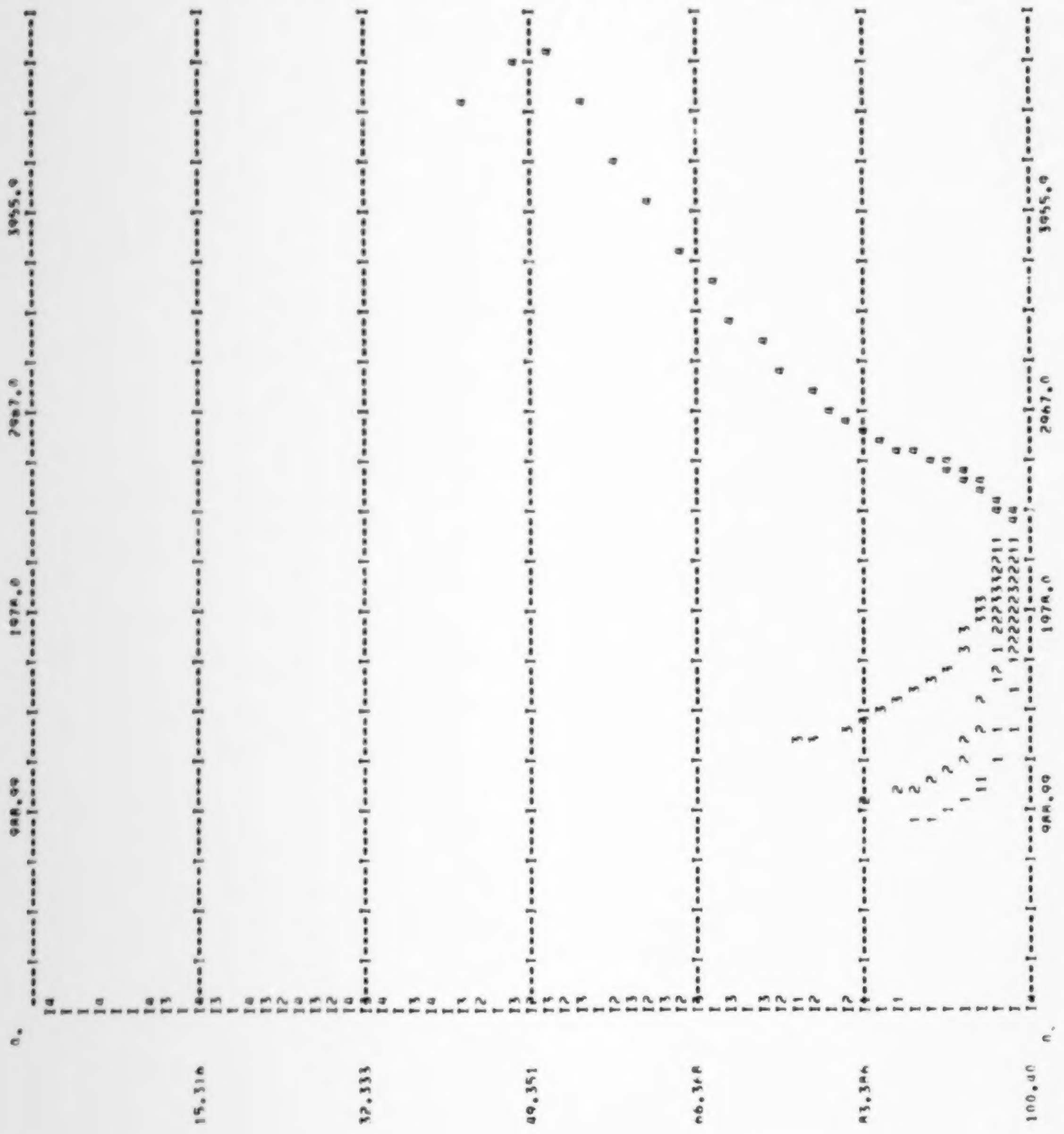
RUN D-L-10

GRAPH OF SIGMA-Z VS Y AT TIMES

290,09454 308,86129 362,85903 1095,4773

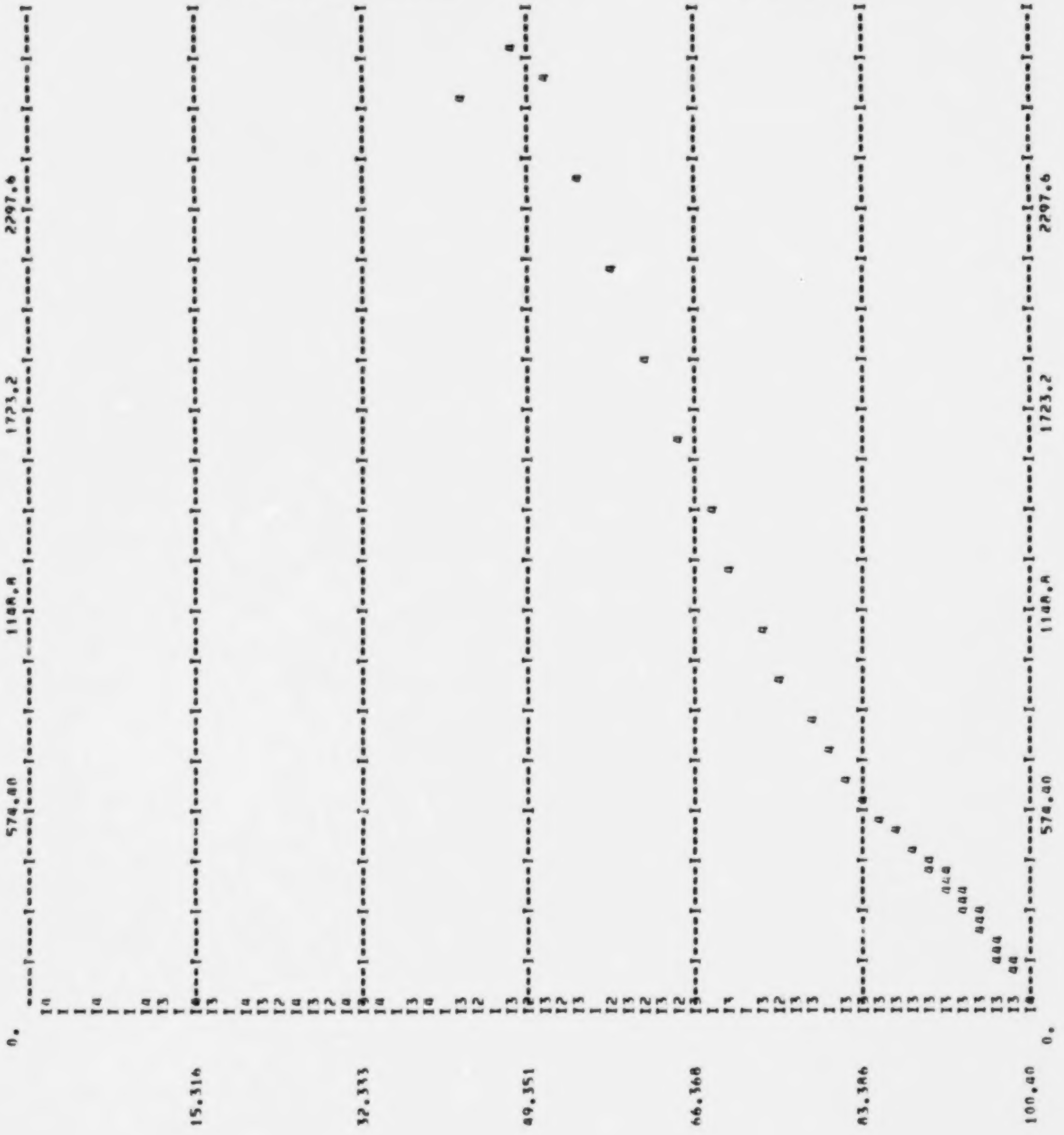
RANGE OF Y PLOTTED 0. 100,80299

RANGE OF SIGMA-Z PLOTTED 0. 4897,6807



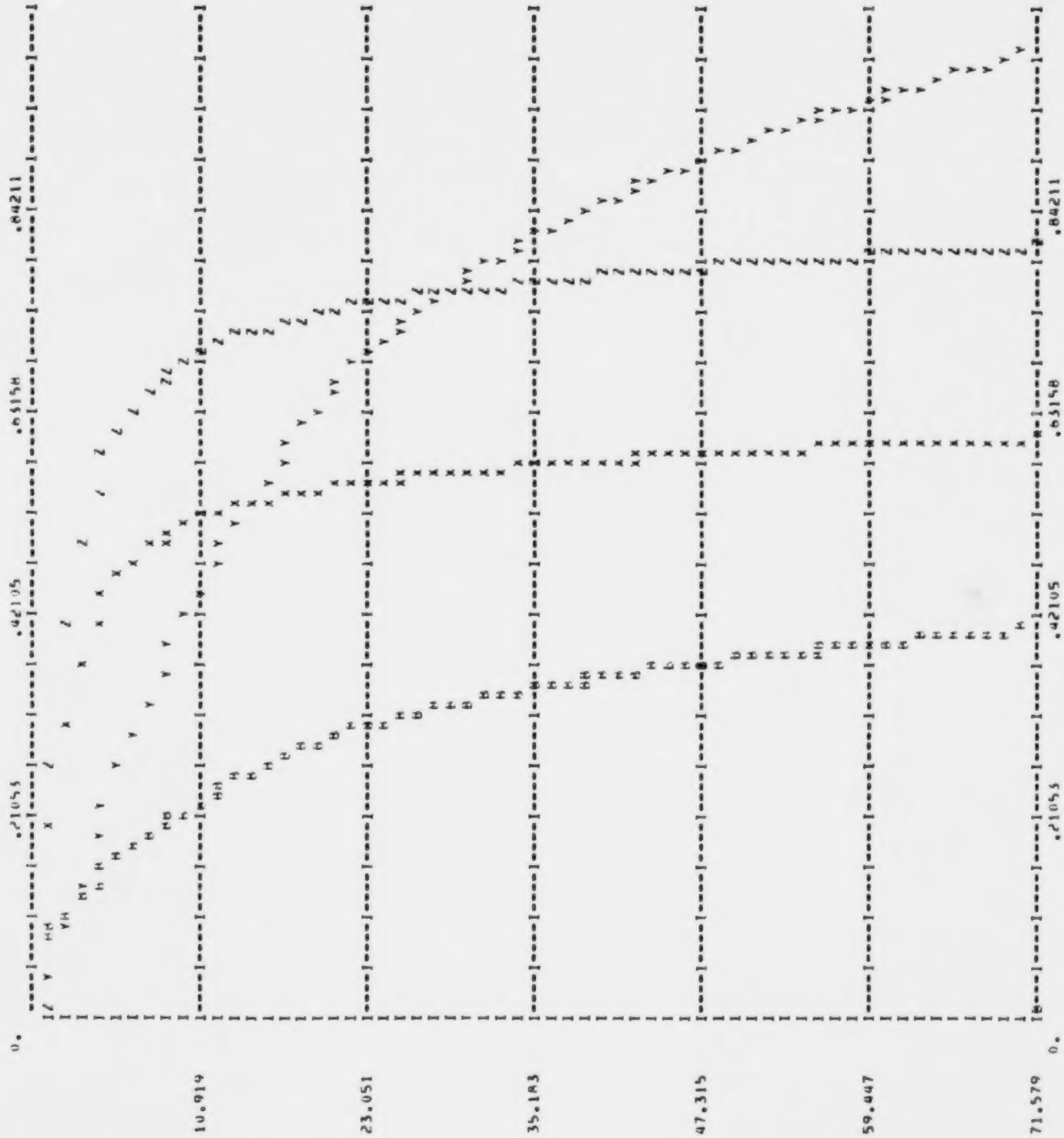
RUN D-L-10

```
                       GRAPH OF SIGMAXZ VS Y AT TIMES
299.49454          308.86129          362.85903          1095.4773

    RANGE OF    Y    PLOTTED         0.                100.40299
    RANGE OF SIGMAXZ PLOTTED         0.                2728.4094
```



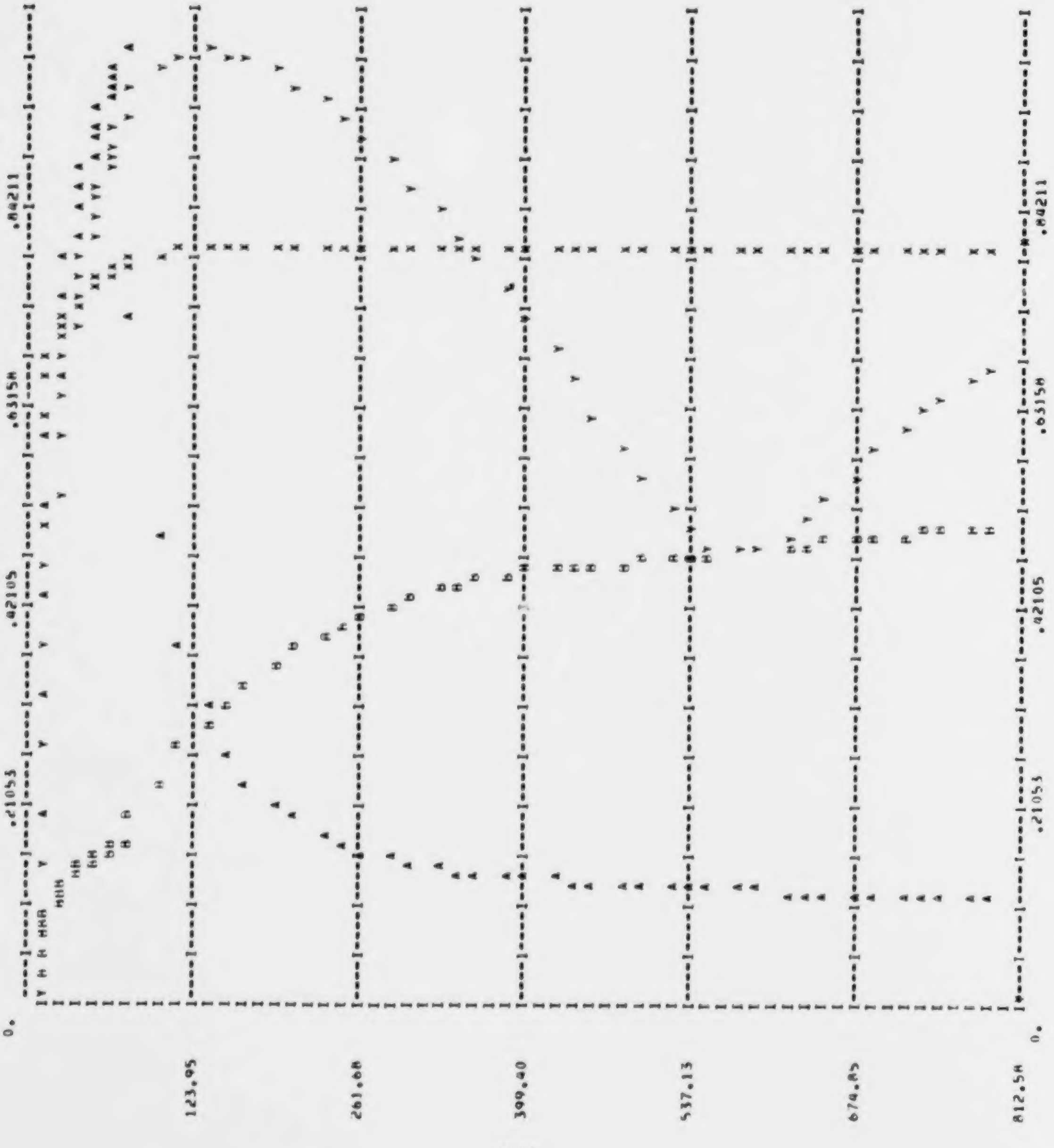
RUN D-L-11

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          71.579

                    DEPENDENT VARIABLES

SYMBOL            Y            H            X            Z
MAX PLOTTED     90.209       26.274       2.4631       2.4631
MIN PLOTTED     0.           0.           0.           0.
REMARKS         VERT. DIST.    RADIUS       HOR. DIST.   HOR. DIST.
```



RUN D-L-11

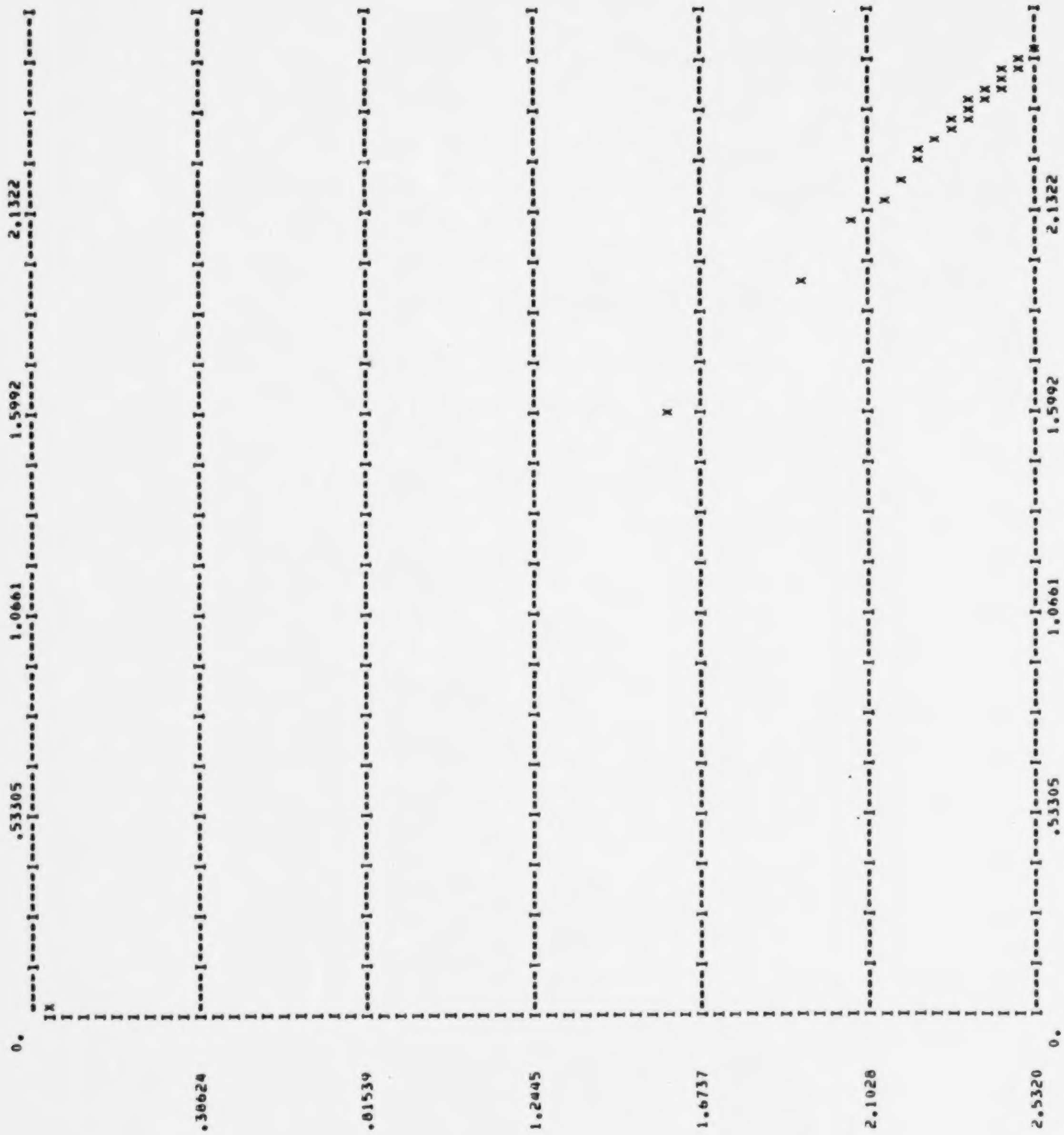
```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          812.58

                         DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     13.076         81.604         2.5320         96.381
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



RUN D-L-11

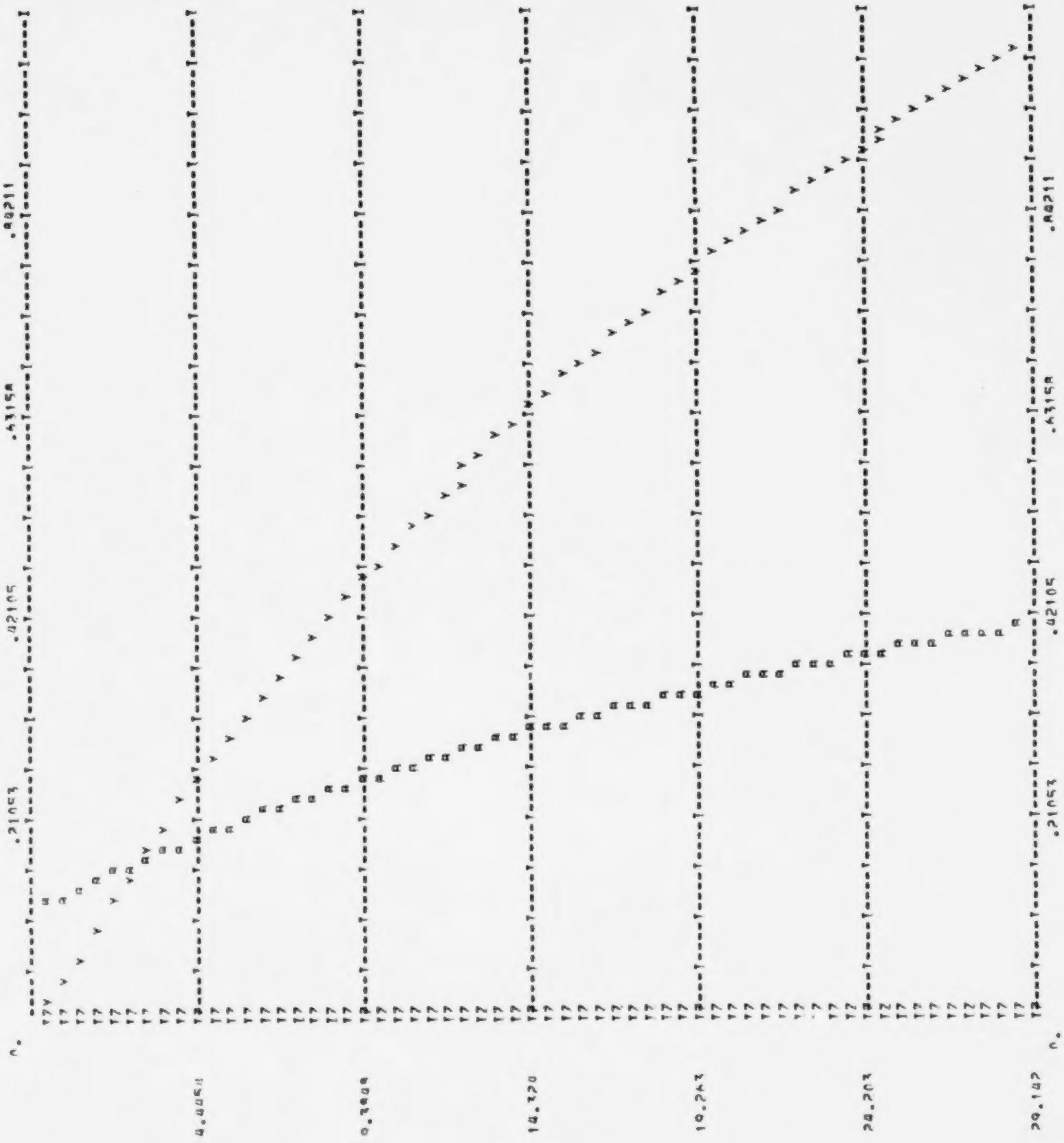
GRAPH OF X VS Z

```
RANGE OF X       0.                       2.5319896
RANGE OF Z       0.                       2.5319896
```



RUN D-S-1

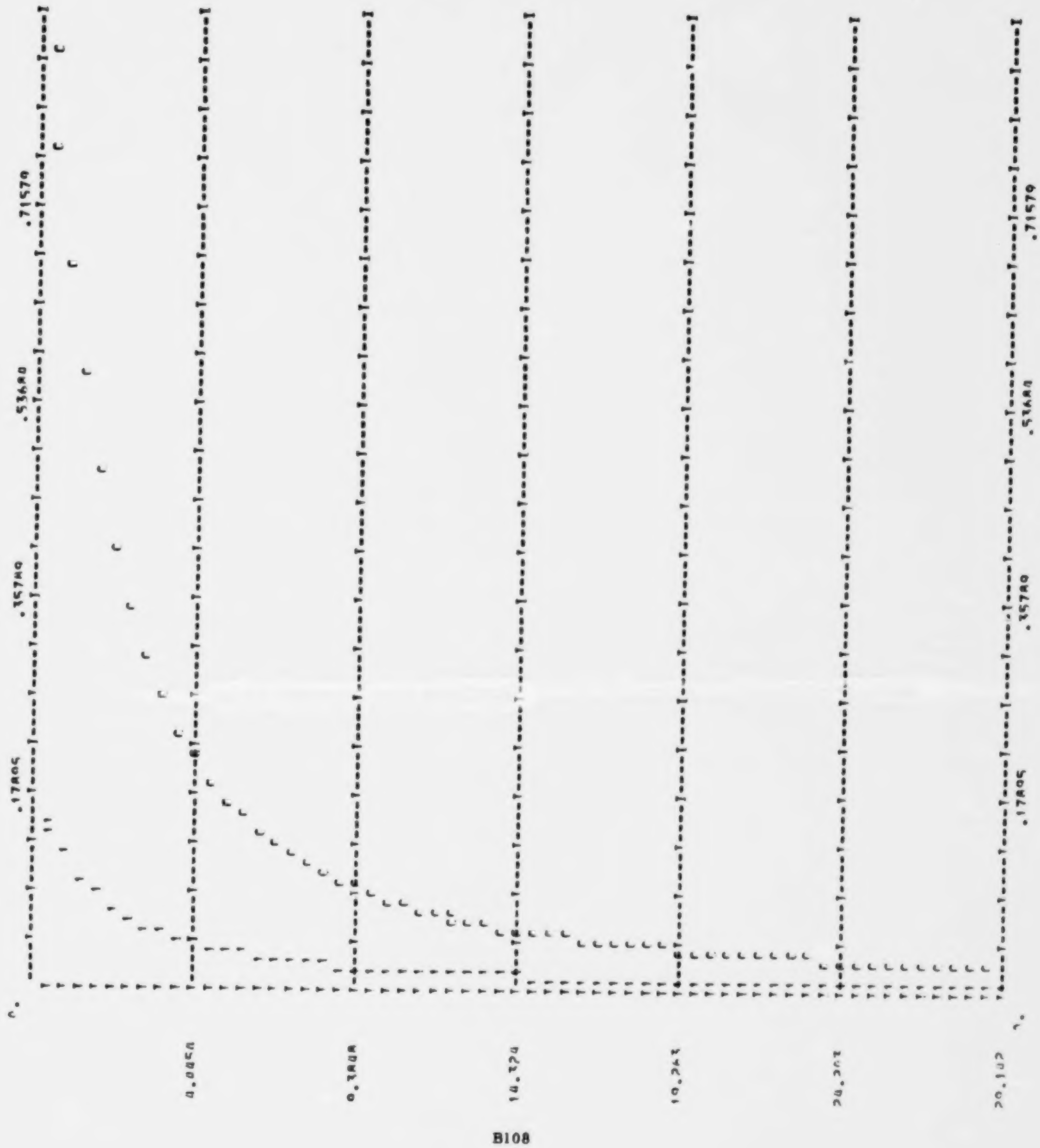
```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           29.142

                    DEPENDENT VARIABLES

SYMBOL              Y             R            X             Z
MAX PLOTTED     52.152        17.256       0.           0.
MIN PLOTTED     0.            0.           0.           0.
REMARKS         VERT. DIST.    RADIUS      HOR. DIST.   HOR. DIST.
```



RUN D-S-1

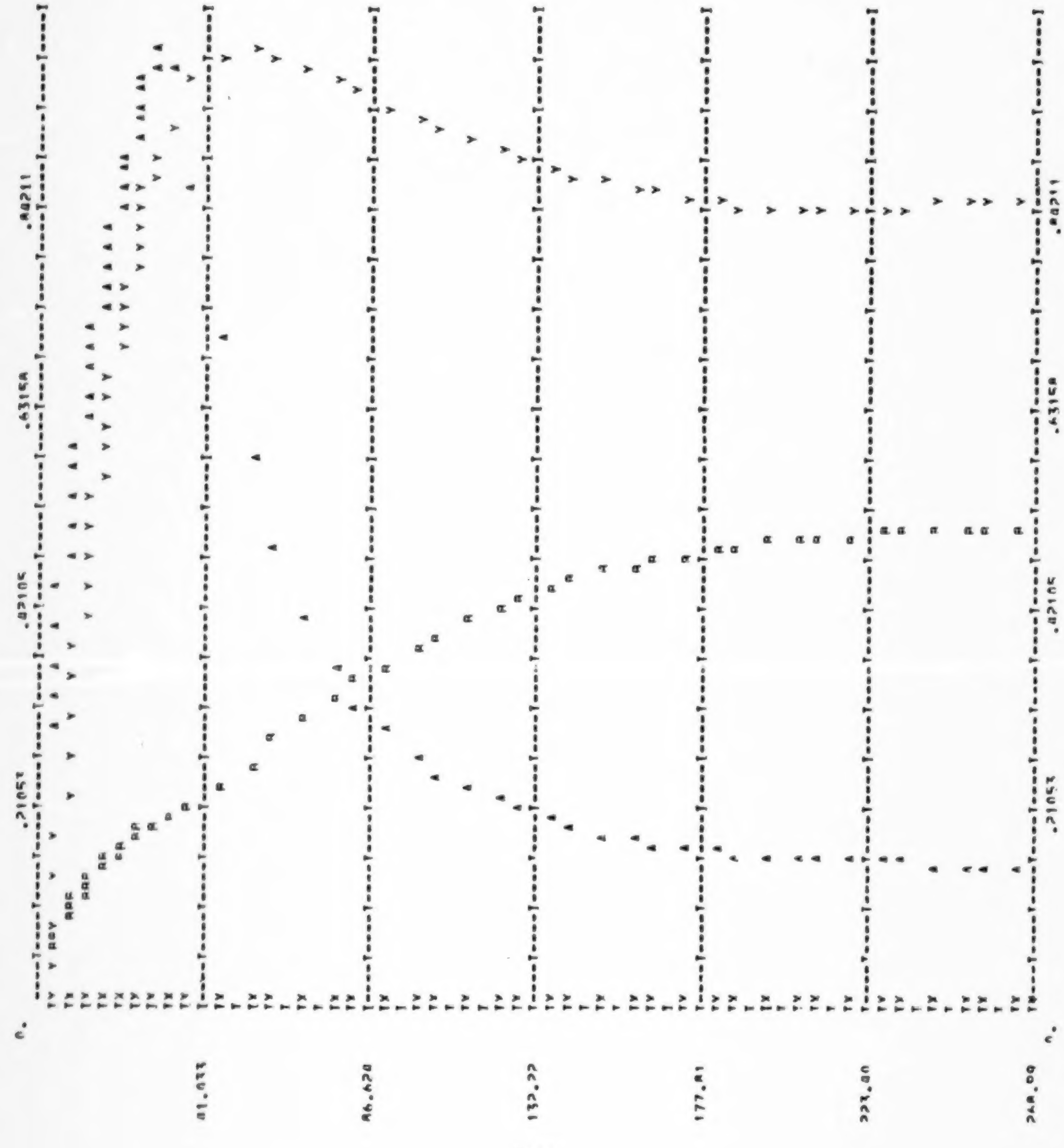
GRAPH OF WASTE CONCENTRATIONS

```
RANGE OF X                              0.                    29.142216
RANGE OF CONCENTRATIONS PLOTTED         0.                    .85000000
```

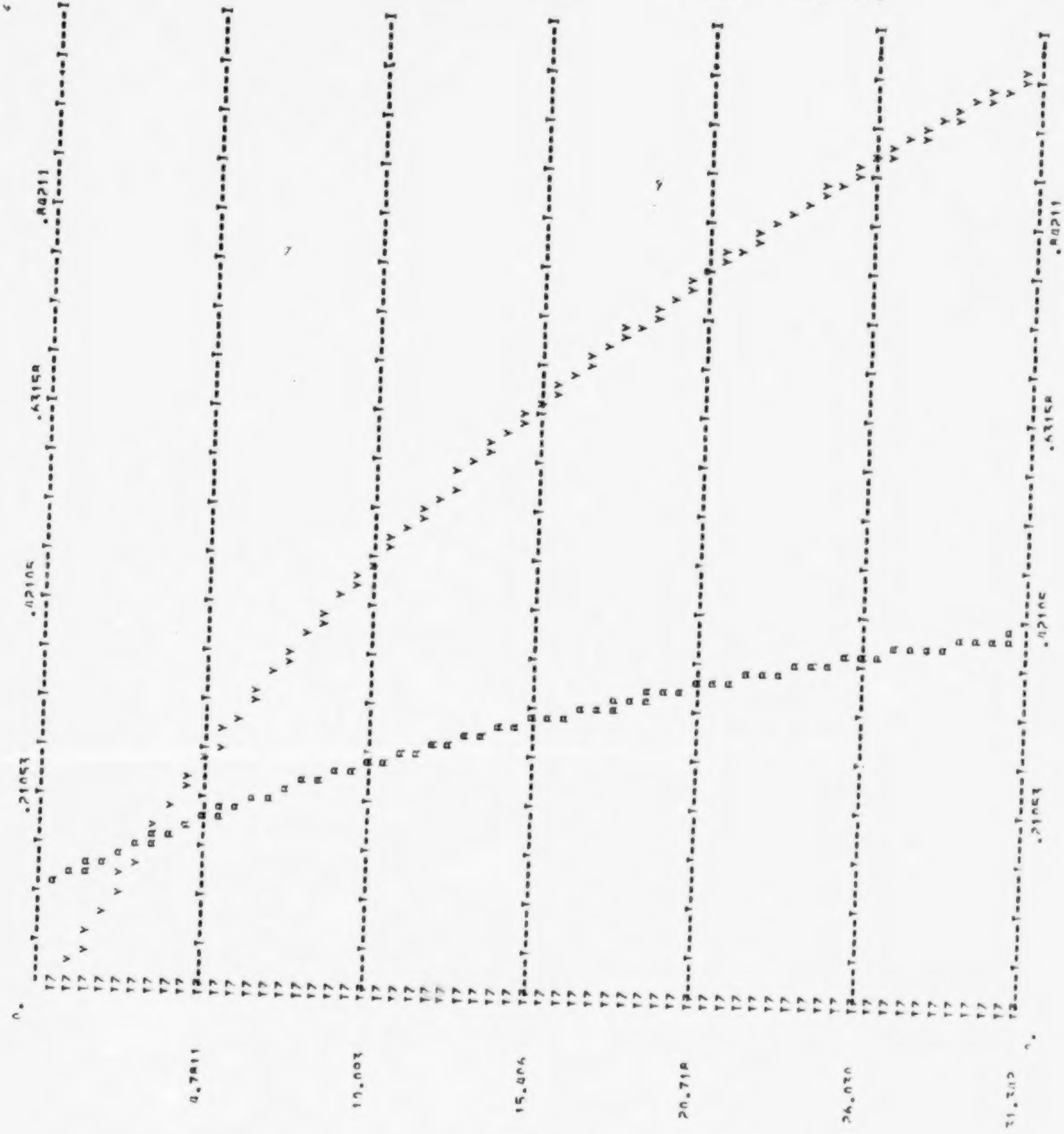


RUN D-S-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          268.99

                        DEPENDENT VARIABLES

SYMBOL              A              B             X             Y
MAX PLOTTED      8.5737         45.693        0.             58.183
MIN PLOTTED     0.             0.             0.            0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



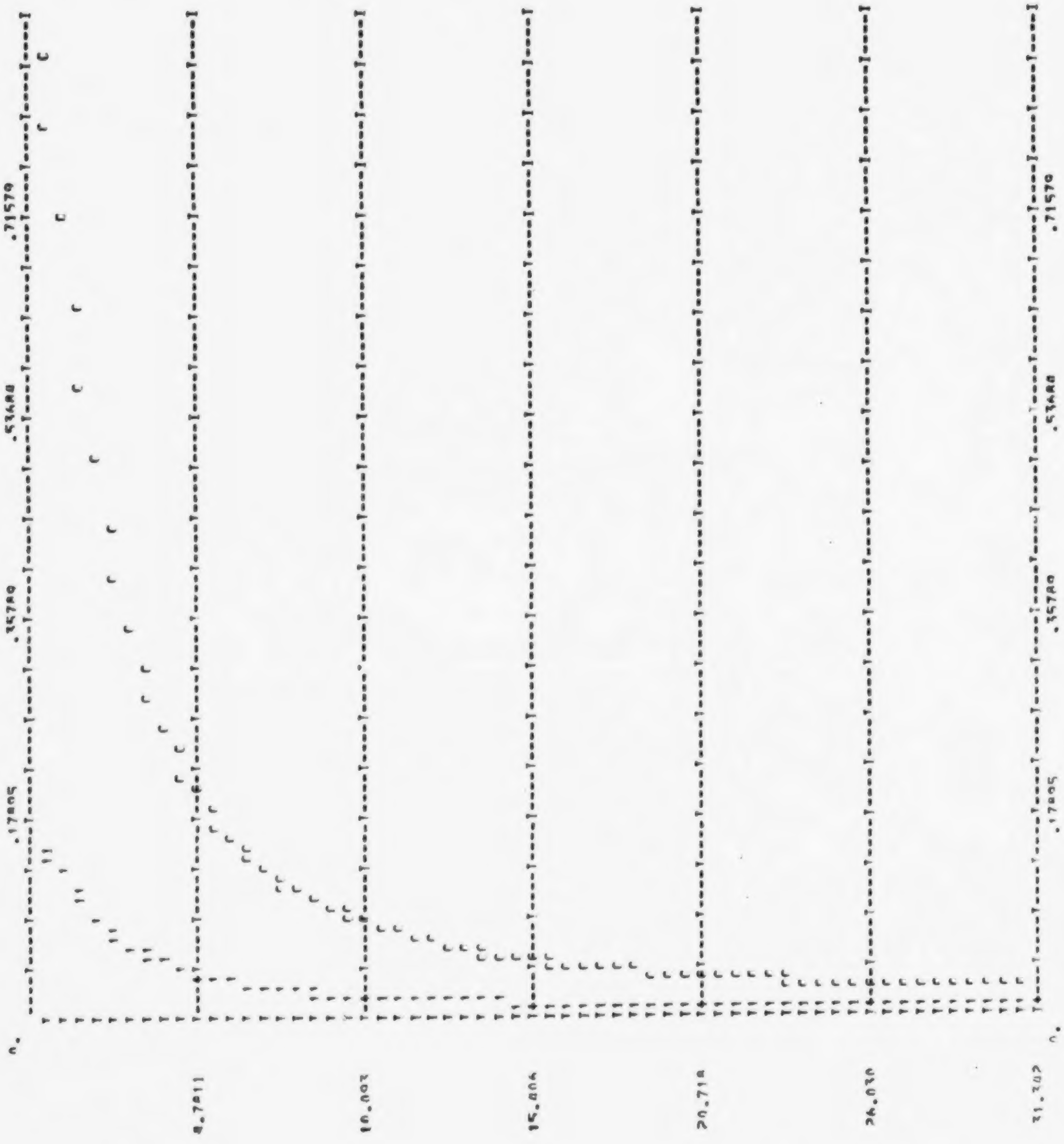
```
                         RUN D-S-2
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          31.342

                     DEPENDENT VARIABLES

SYMBOL                Y              R              X             Z
MAX PLOTTED        58.432         17.791         0.            0.
MIN PLOTTED        0.             0.             0.            0.
REMARKS            VERT. DIST.    RADIUS         HOR. DIST.    HOR. DIST.
```



RUN D-S-2

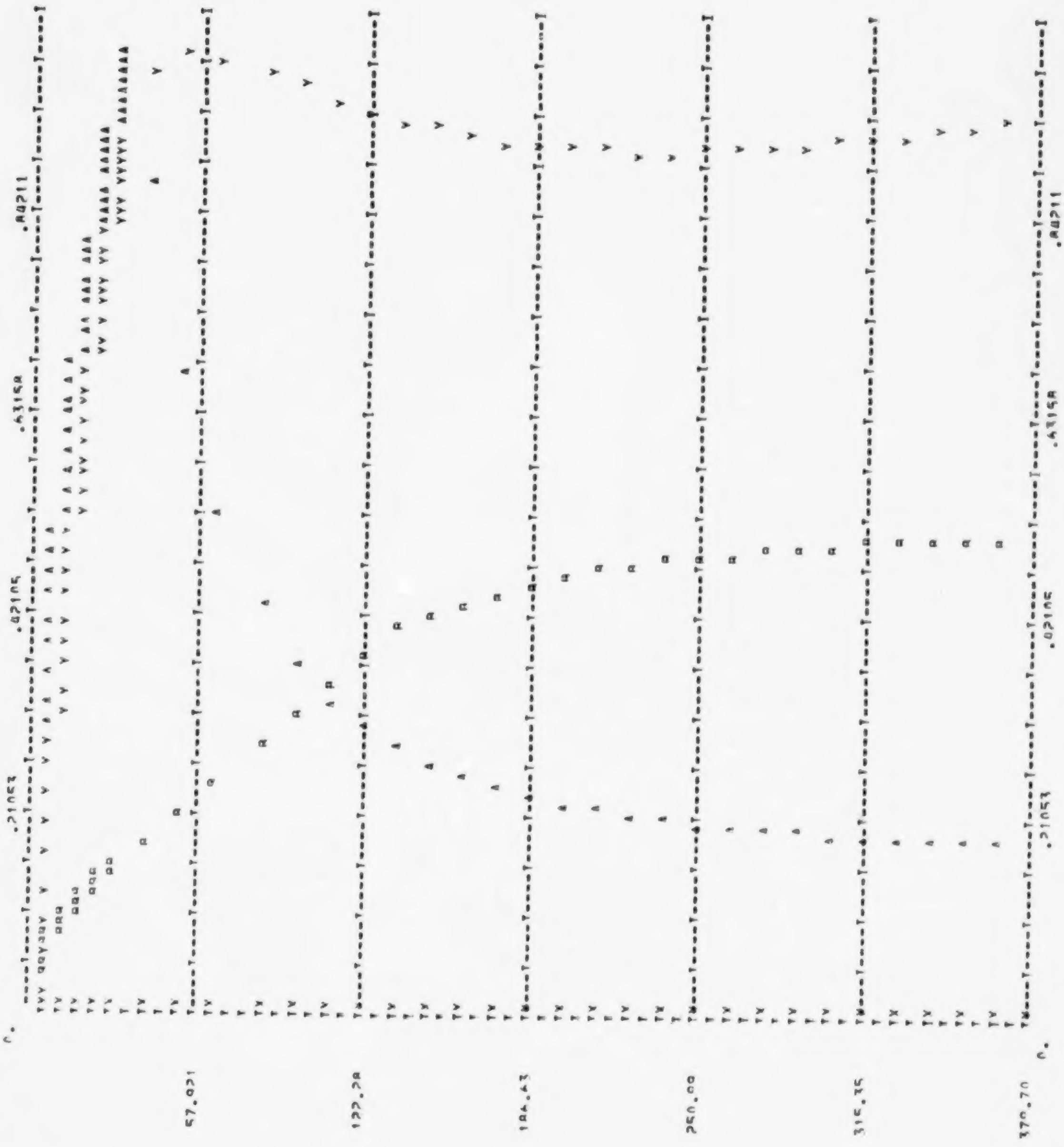
GRAPH OF WASTE CONCENTRATIONS

RANGE OF Y 0. 31.302856
RANGE OF CONCENTRATIONS PLOTTED 0. .85000000



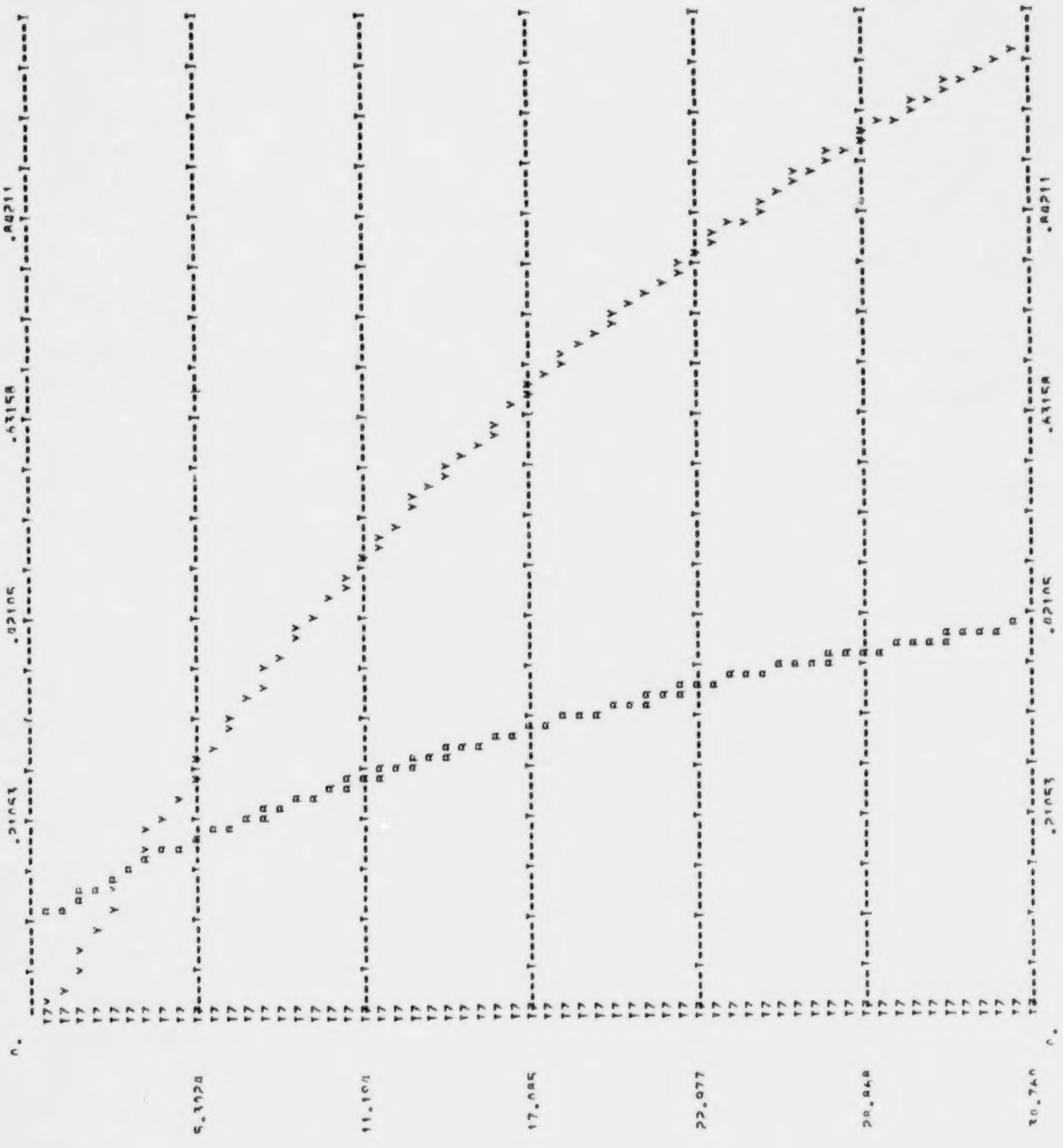
RUN D-S-2

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          379.70

                    DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     8.8957         59.588         0.             59.768
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



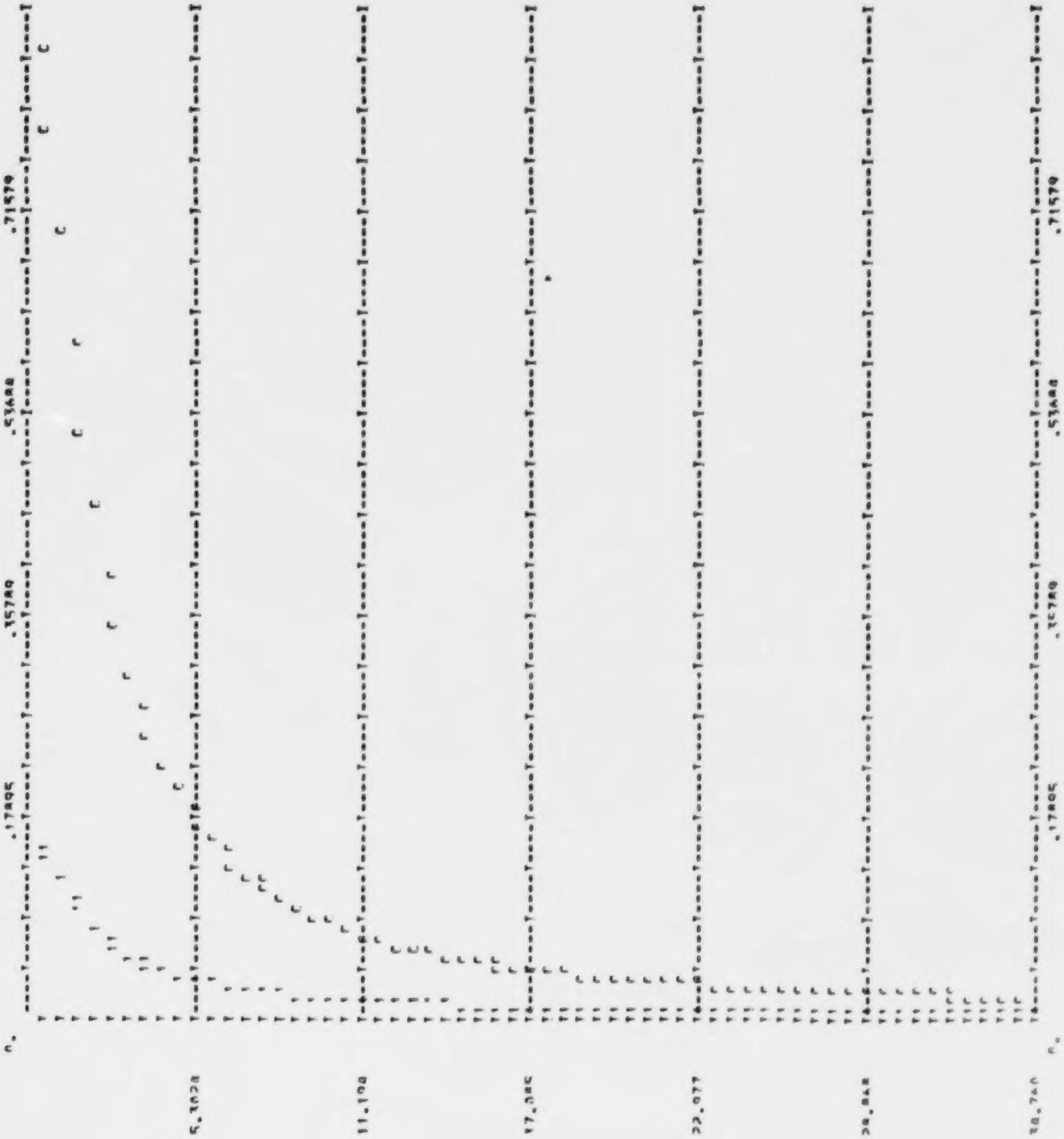
RUN D-S-3

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          30.760

                          DEPENDENT VARIABLES

SYMBOL              V              R              X              Z
MAX PLOTTED     57.436         18.504         0.             0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



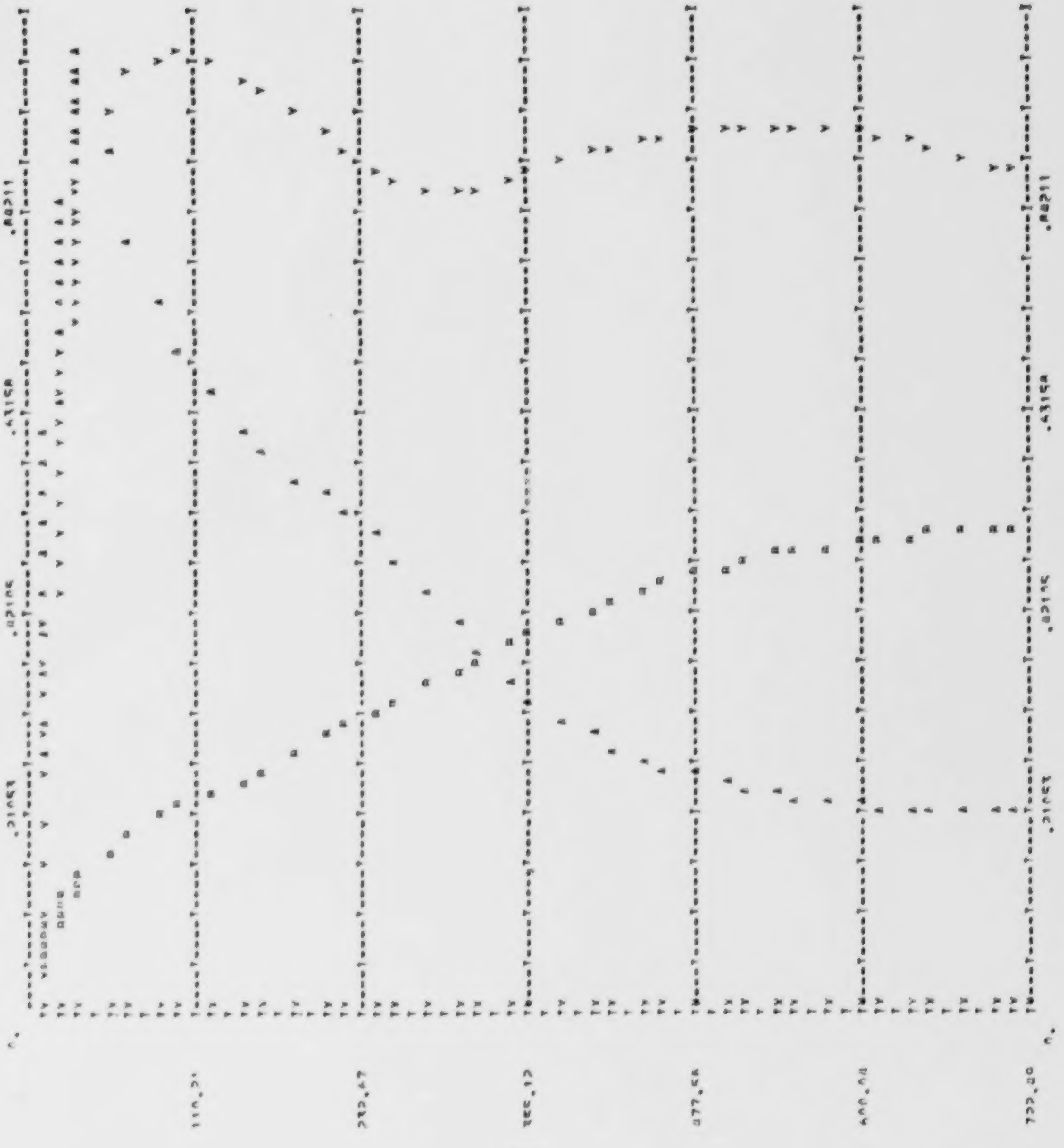
RUN D-S-3

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                    30.759862
RANGE OF CONCENTRATIONS PLOTTED         0.                    .85000000
```



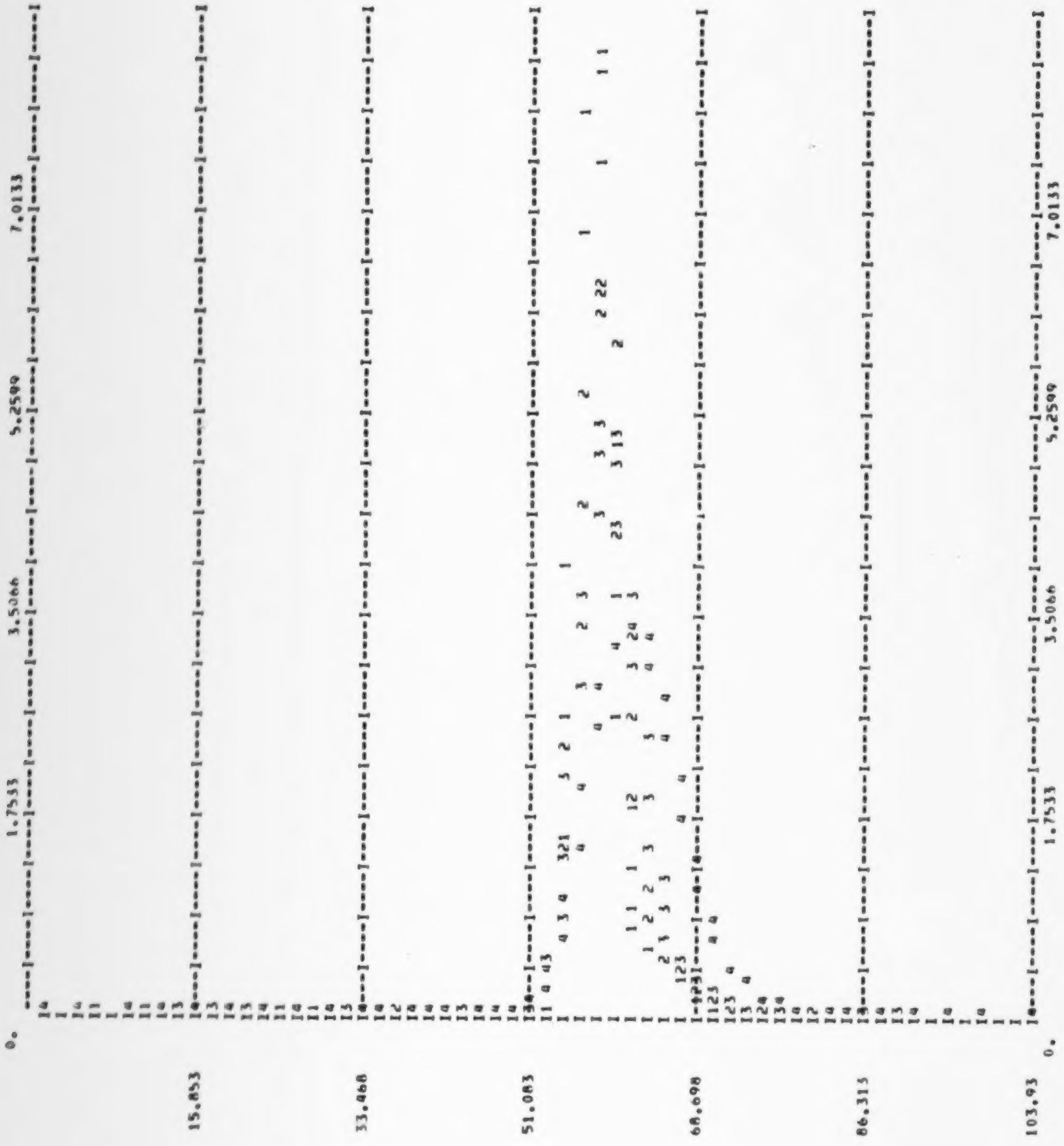
RUN D-S-3

```
INDEPENDENT VARIABLE IS   TIME     OVER RANGE     0.          722.89

                         DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED      0.2722         65.798         0.            66.083
MIN PLOTTED      0.             0.             0.            0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.    VERT. DIST.
```



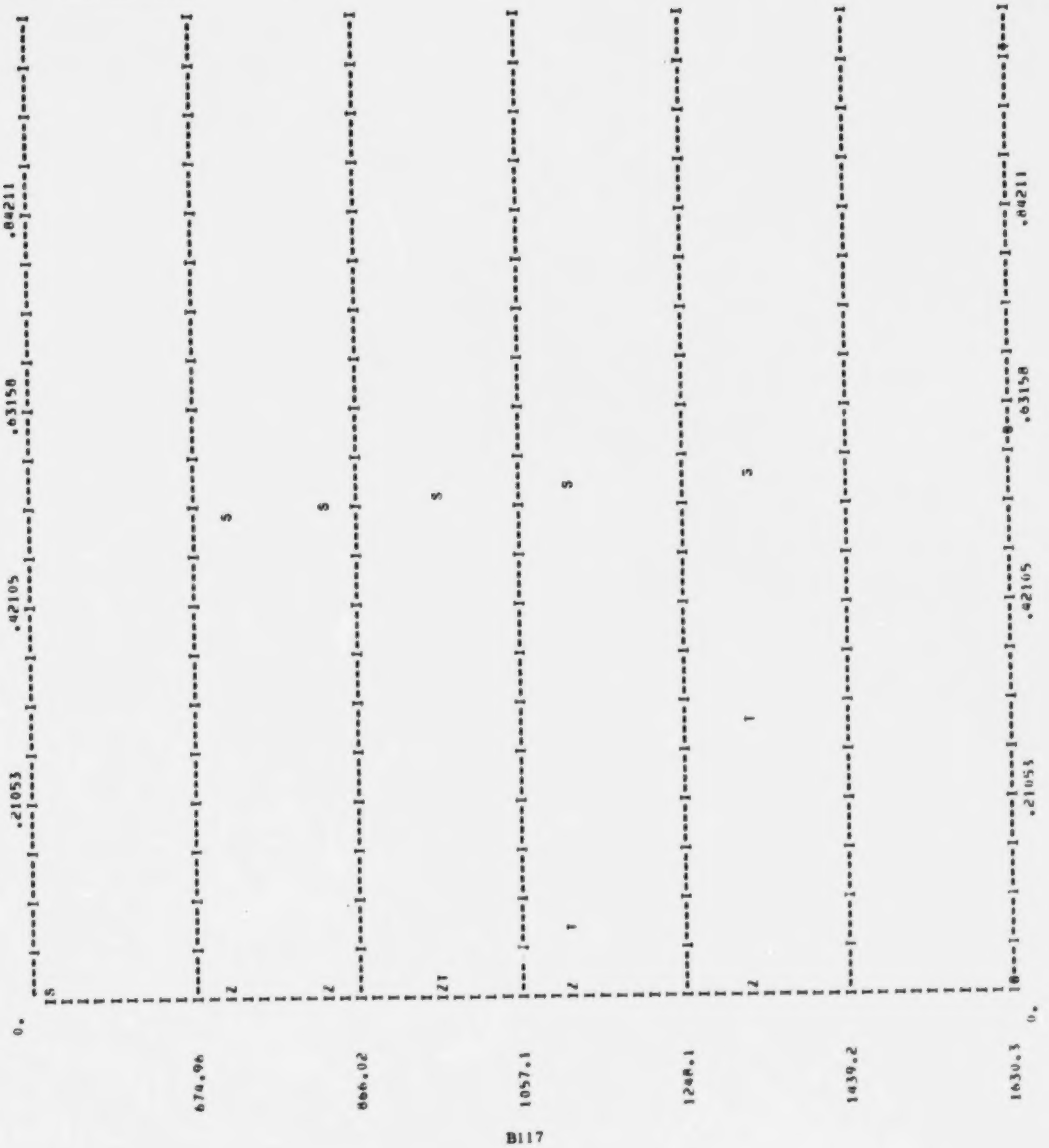
RUN D-S-3

```
                           GRAPH OF   COD   VS Y AT TIMES
845.22953              967.33600          1127.0914            1630.2585

         RANGE OF    Y    PLOTTED        0.                 103.92772
         RANGE OF   COD   PLOTTED        0.                 8.3282476
```



RUN D-S-3

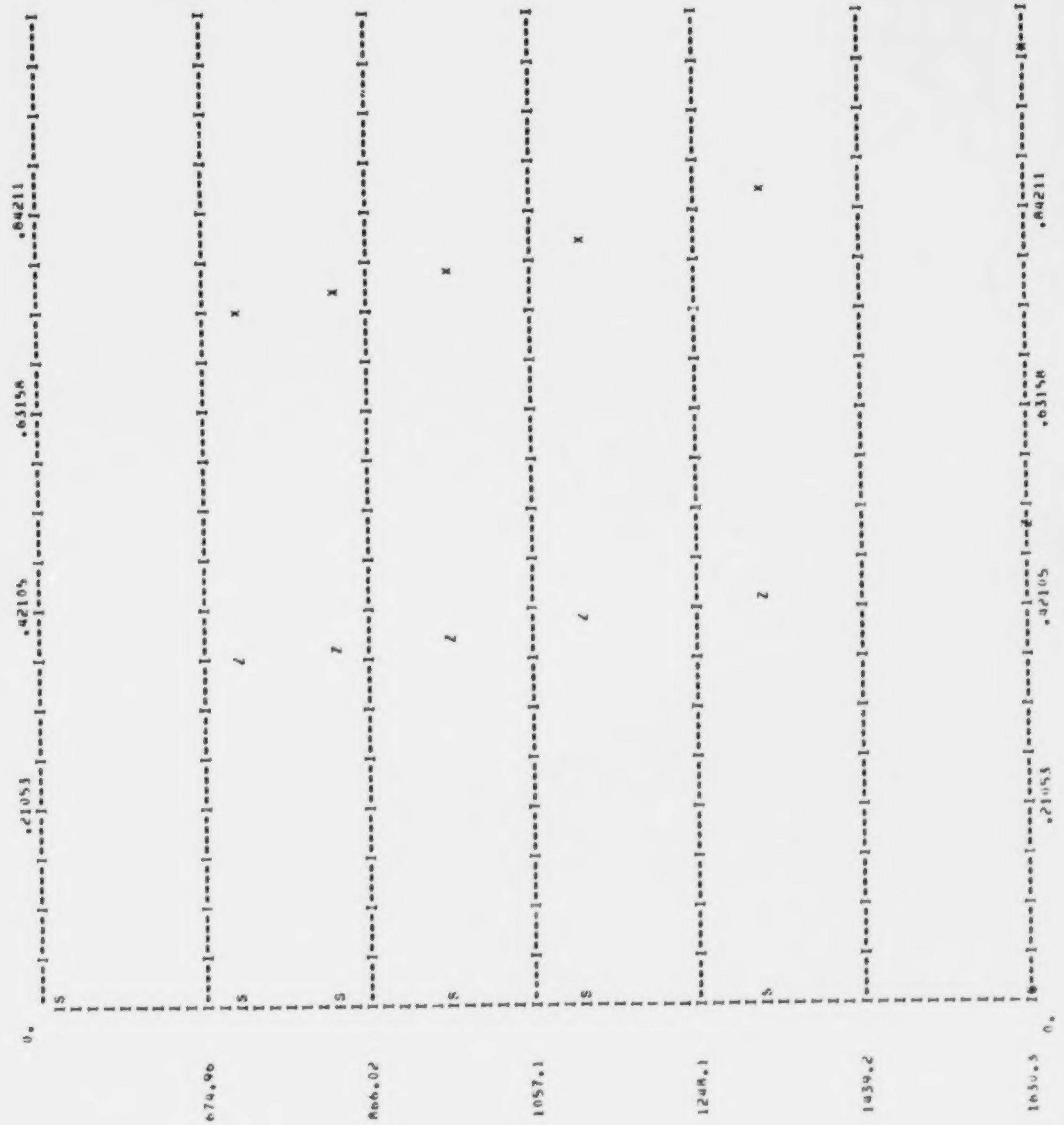
```
PLOT OF TOT BDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE             503.00923          1650.2585                          35.869715
MAXIMUM T,X,Z,S        9.531291846E-04    0.                 0.              0.
MINIMUM T,X,Z,S        0.                 0.                 0.
```



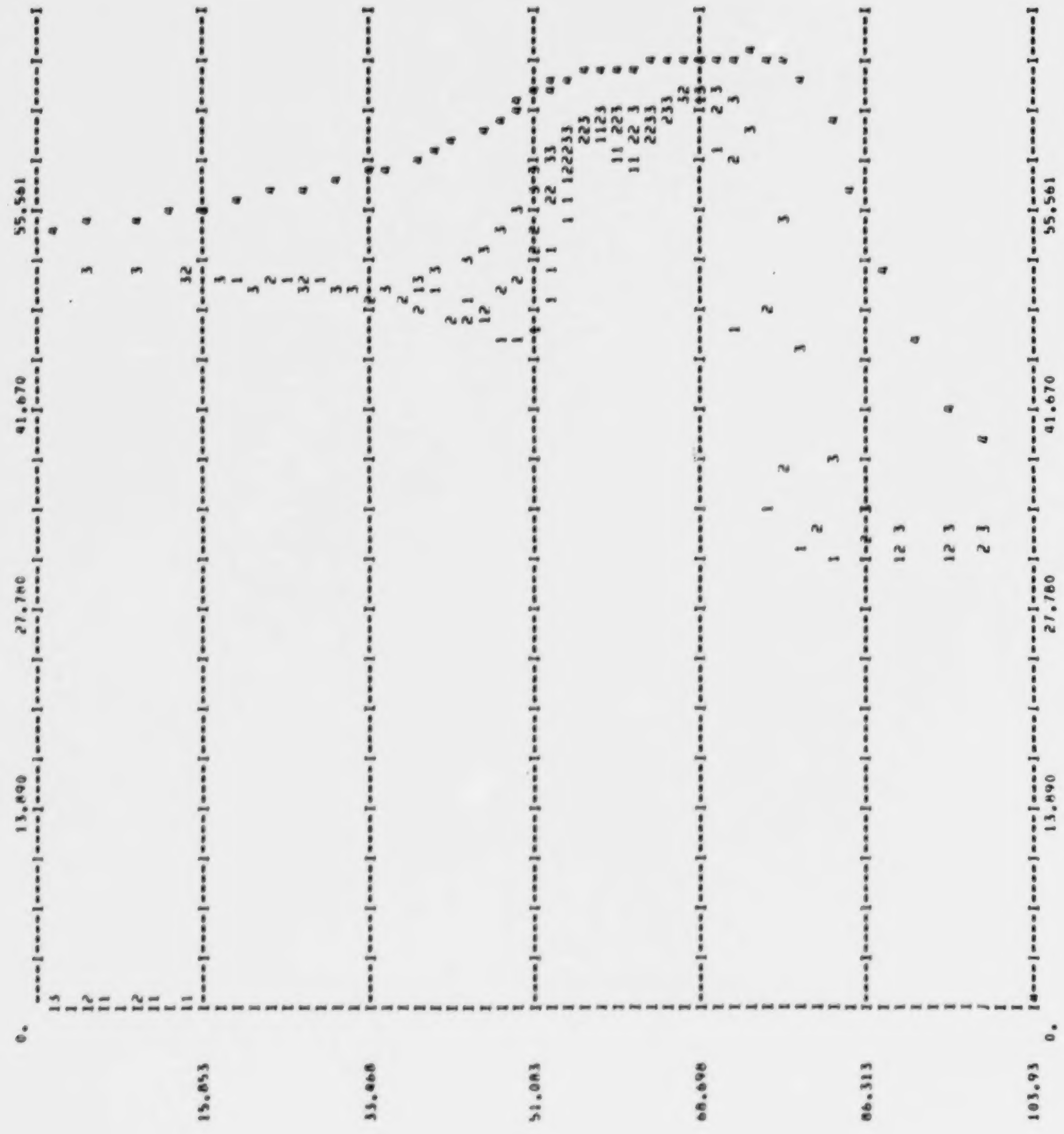
RUN D-S-3

PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

```
TIME RANGE=            503.00923            1630.2585
MAXIMUM X,Z,S          321.65912            321.65912          0.
MINIMUM X,Z,S        0.                   0.                   0.
```

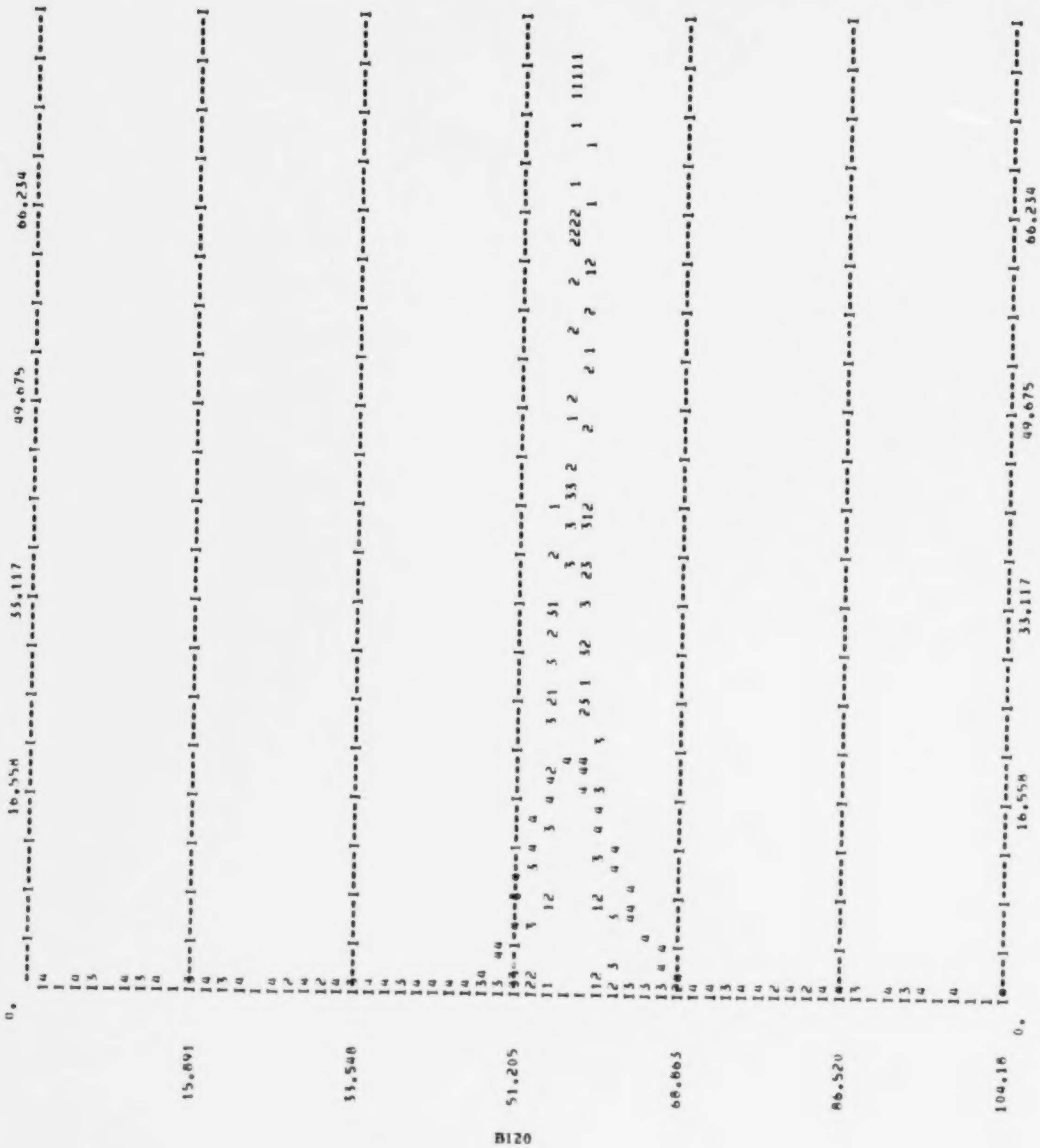


```
                              RUN D-S-3
                        GRAPH OF   SIZE  VS Y AT TIMES
     845.22953            967.33600          1127.0914            1630.2585
            RANGE OF    Y    PLOTTED       0.                   103.92772
            RANGE OF   SIZE  PLOTTED       0.                   65.978239
```



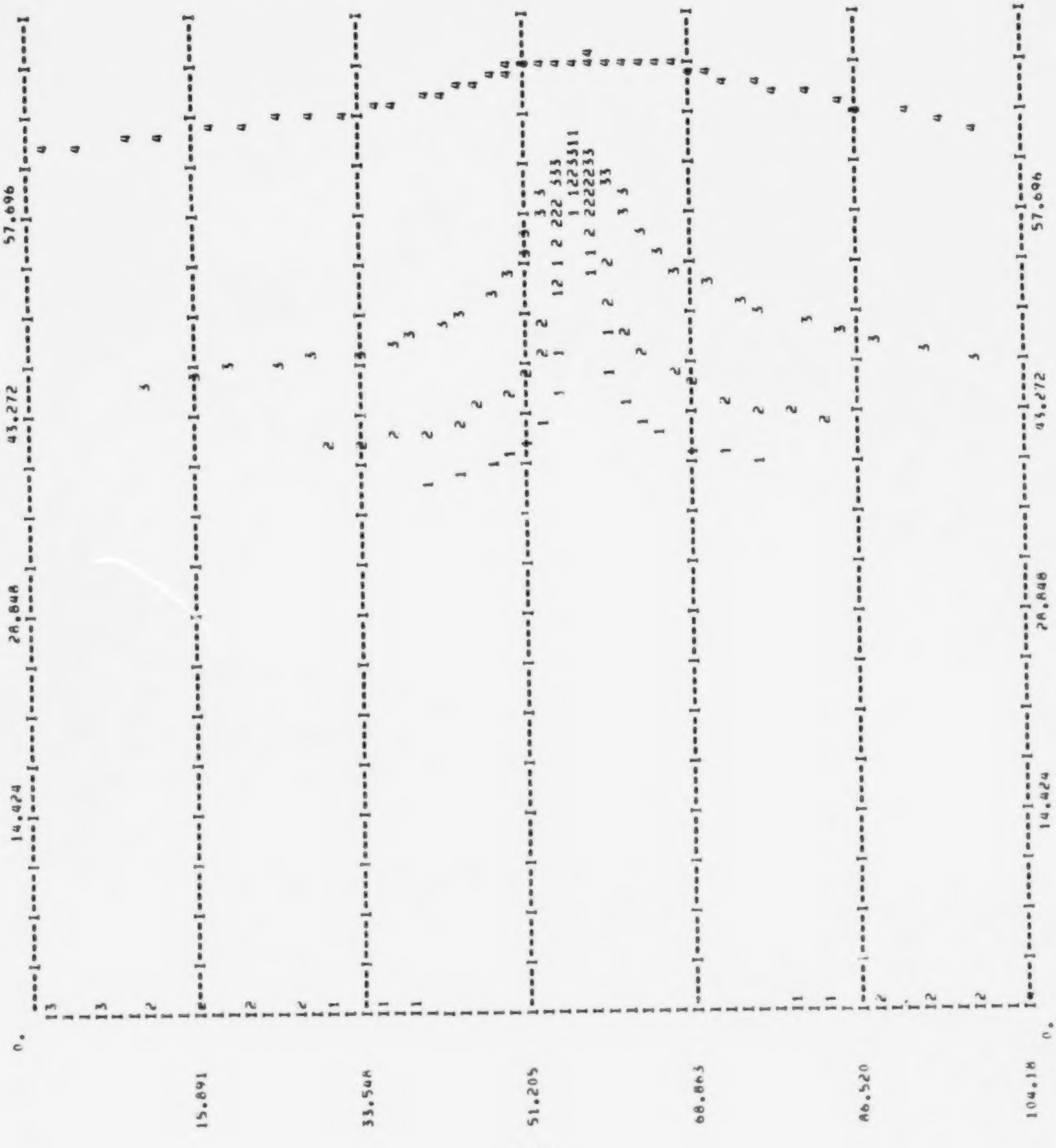
RUN D-S-3 Fluid part of waste

```
                          GRAPH OF    COD   VS Y AT TIMES
750.17537               797.76485         983.01242          2202.6307

        RANGE OF    Y    PLOTTED      0.                  104.17670
        RANGE OF   COD   PLOTTED      0.                  78.652769
```

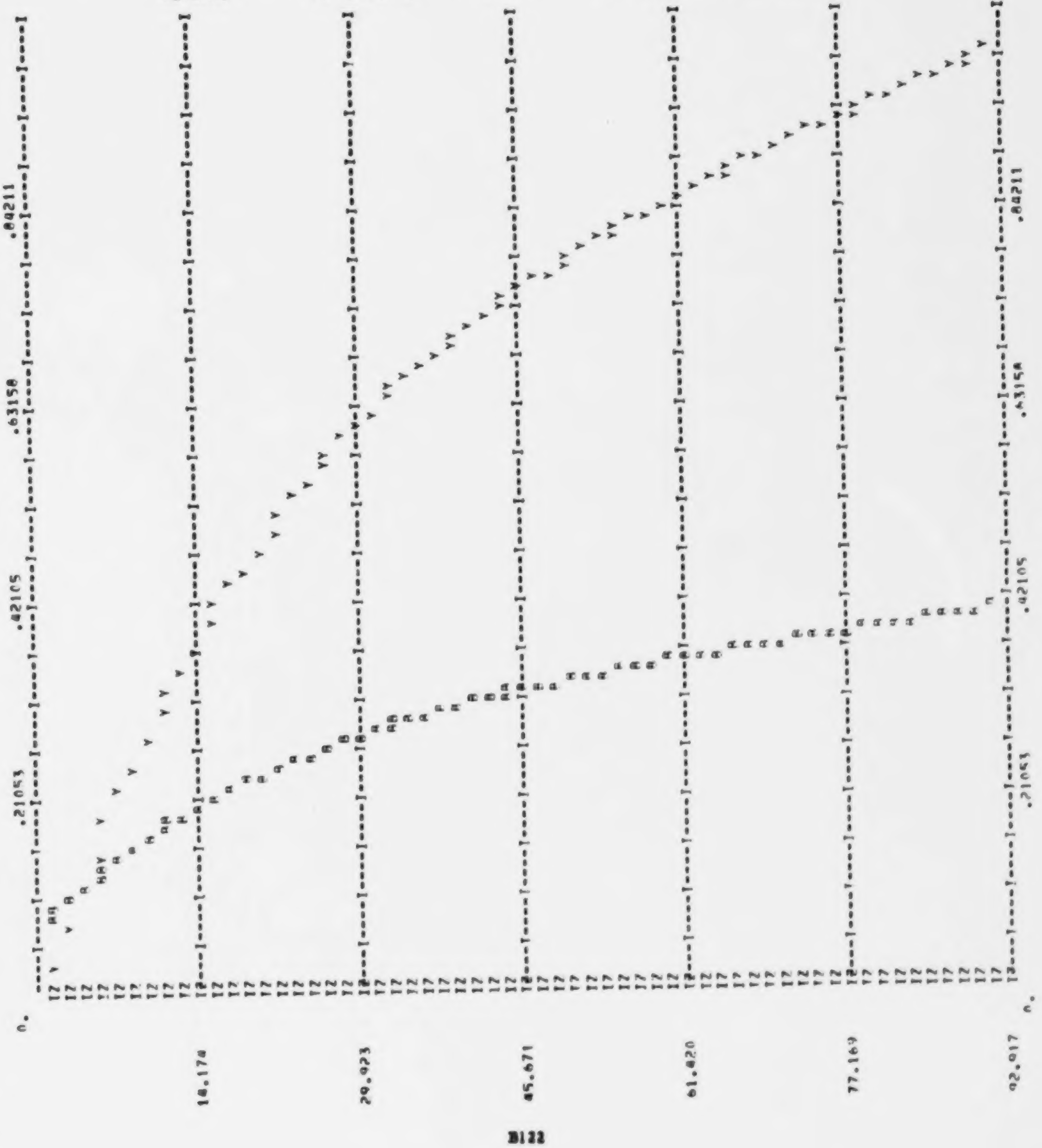


RUN D-S-3   Fluid part of waste

```
                              GRAPH OF   SIZE  VS Y AT TIMES
     750.17337           797.76485             983.01242            2202.6307

          RANGE OF     Y    PLOTTED          0.                  104.17670
          RANGE OF   SIZE   PLOTTED          0.                  68.513458
```

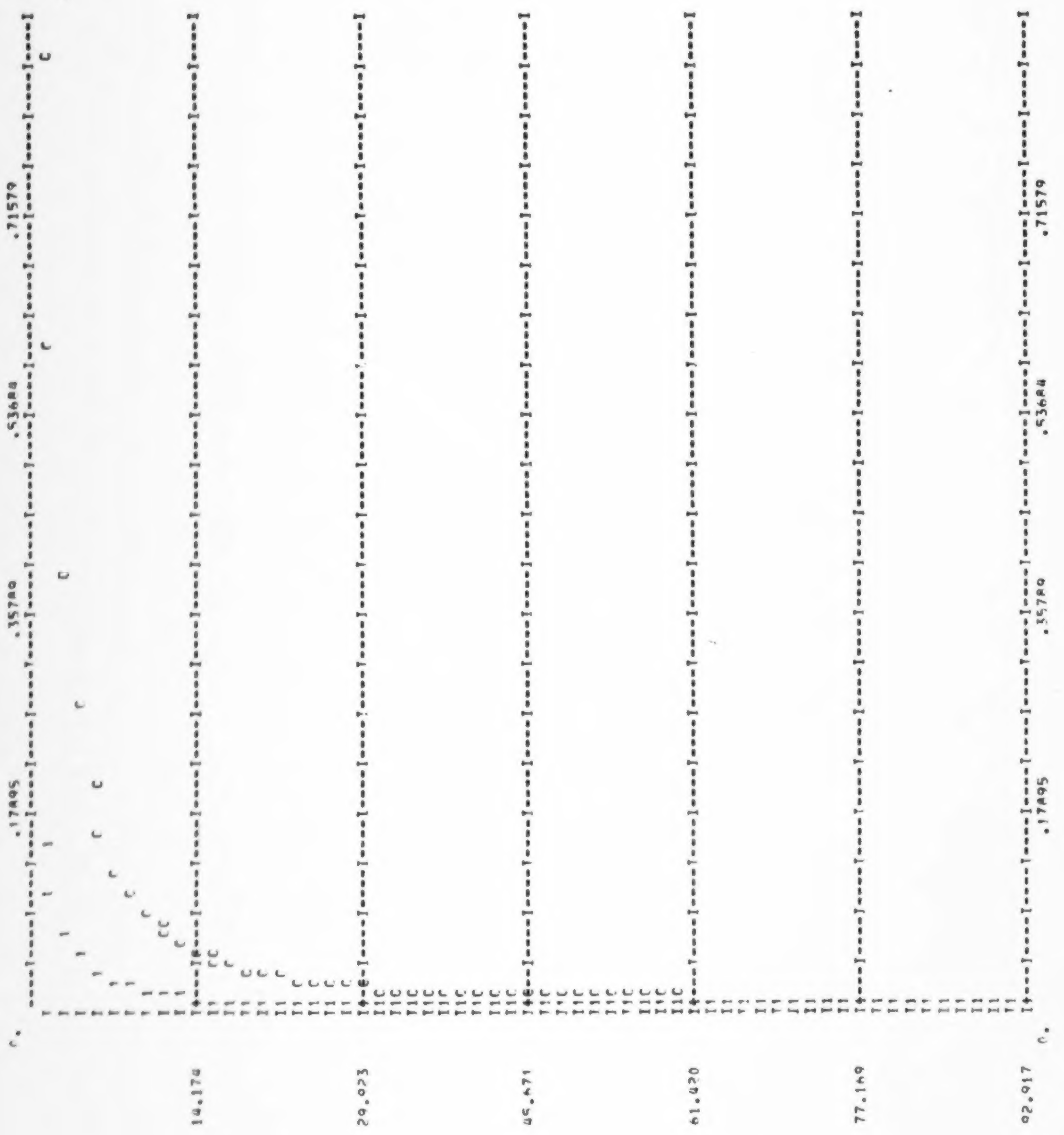


```
                              RUN D-S-4
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          92.917

                        DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED      90.323         26.226         0.             0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



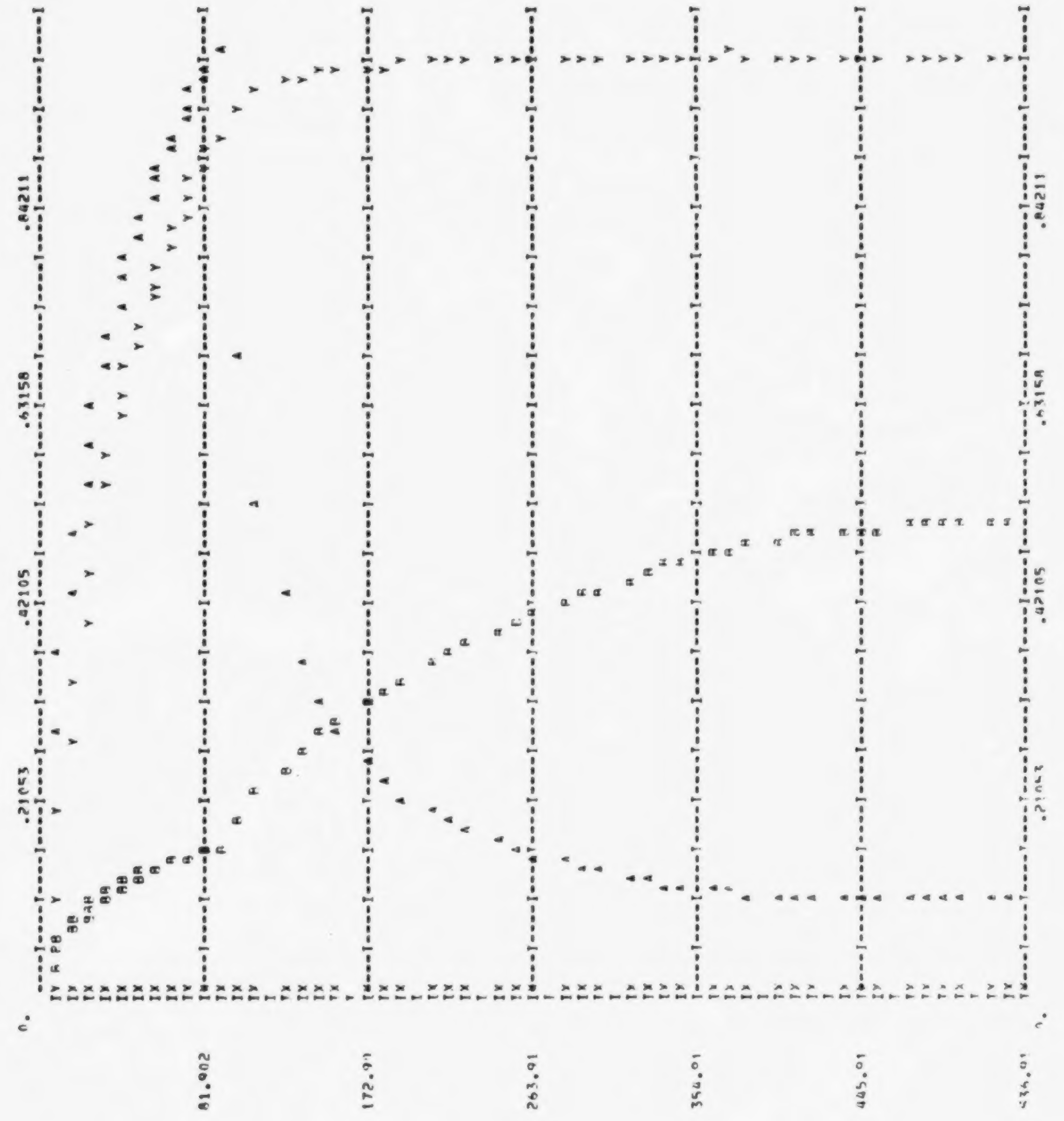
RUN D-S-4

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                      92.917473
RANGE OF CONCENTRATIONS PLOTTED         0.                      .85000000
```



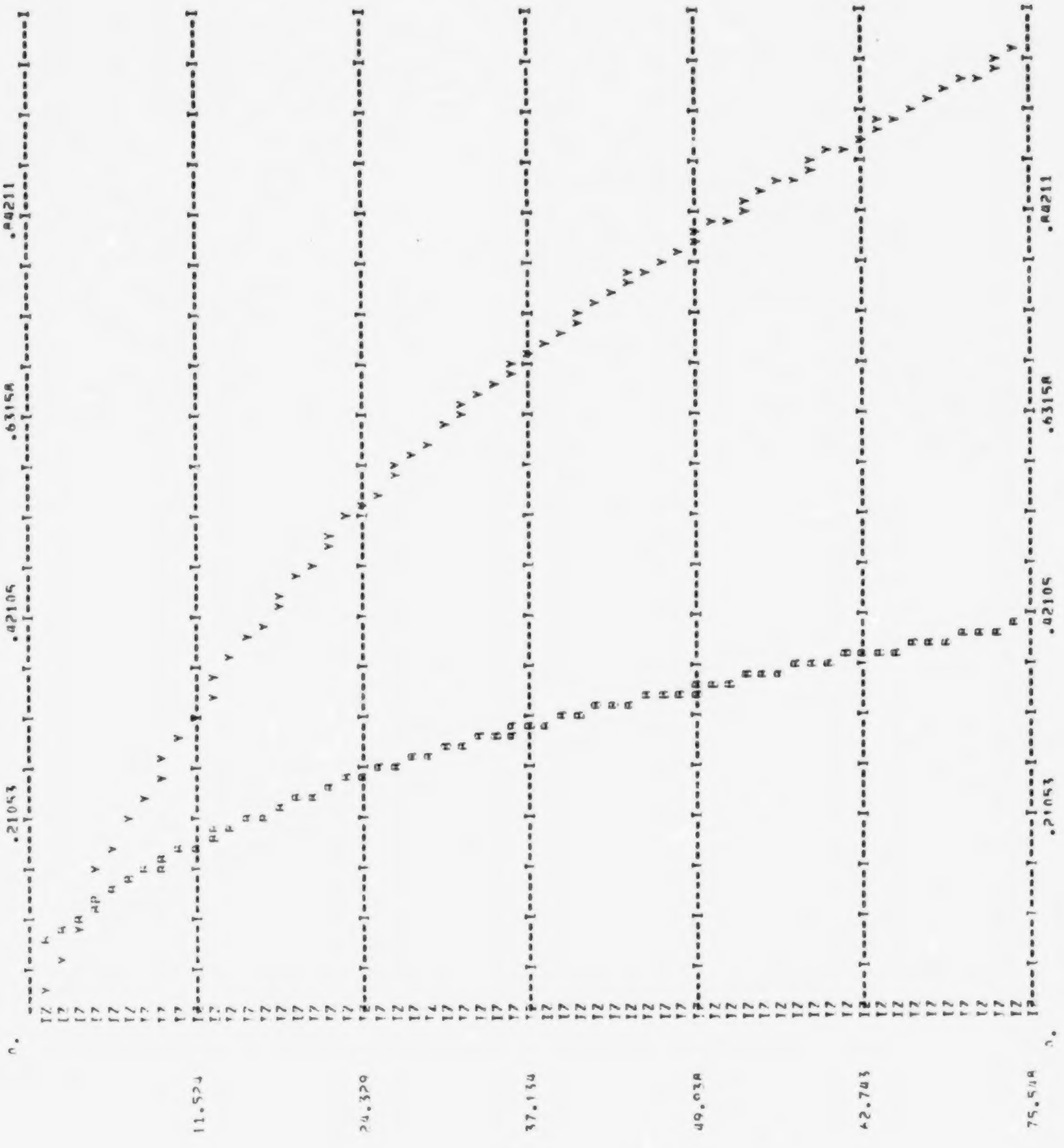
RUN D-S-4

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE    0.          536.91

                   DEPENDENT VARIABLES

                    A            B            X           Y
SYMBOL                                                  99.095
MAX PLOTTED     13.113       85.663       0.          0.
MIN PLOTTED     0.           0.           0.          VERT. DIST.
REMARKS         VERT. SIZE.  HOR. SIZE    HOR. DIST.
```



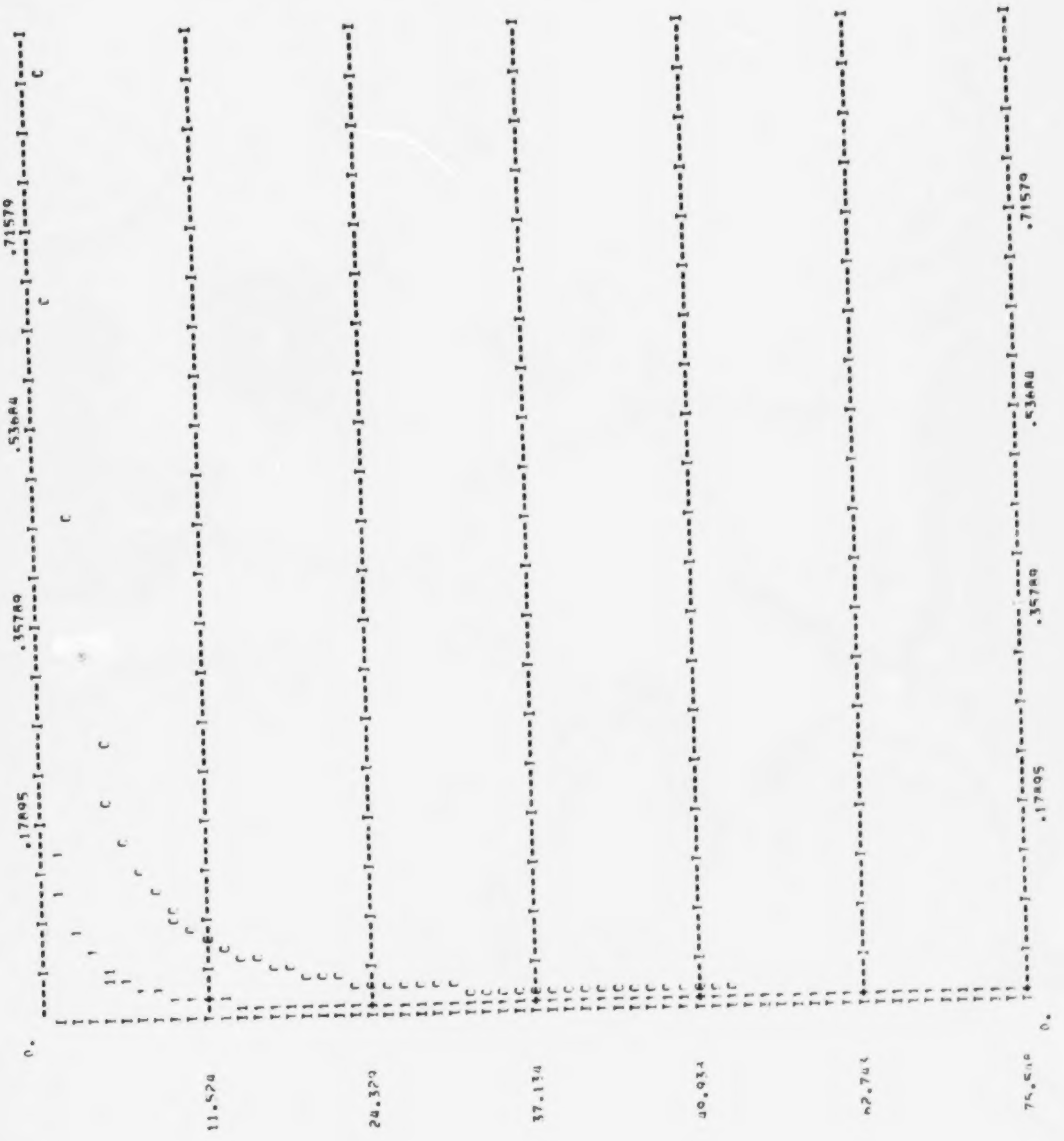
RUN D-S-5

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          75.548

                    DEPENDENT VARIABLES

SYMBOL              Y               R              X             Z
MAX PLOTTED       90.391         26.242         0.            0.
MIN PLOTTED      0.             0.              0.            0.
REMARKS          VERT. DIST.     RADIUS         HOR. DIST.    HOR. DIST.
```



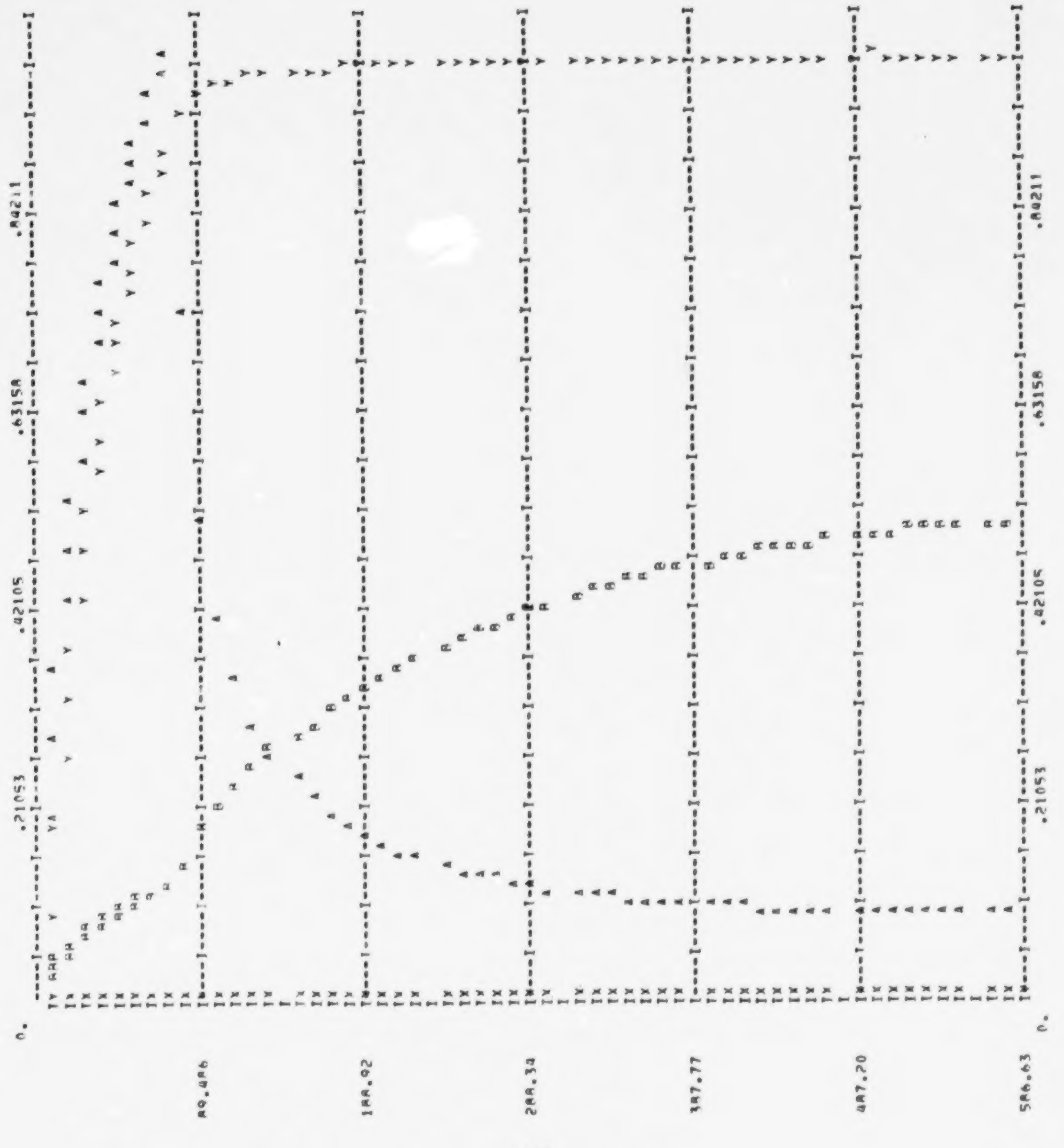
RUN D-S-5

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                          0.                   75.547765
RANGE OF CONCENTRATIONS PLOTTED     0.                   .85000000
```



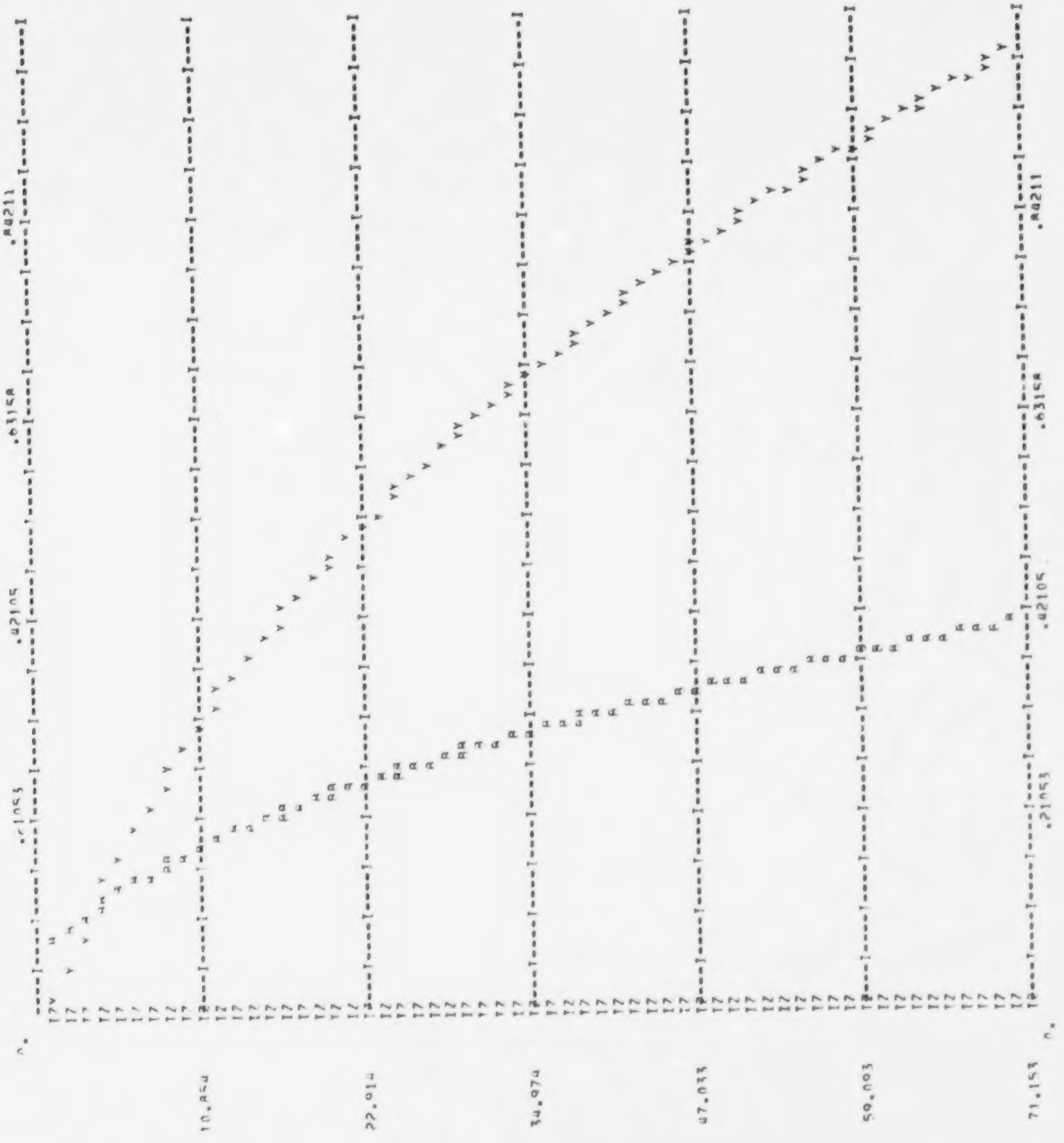
RUN D-S-5

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          586.63

                         DEPENDENT VARIABLES

SYMBOL             A             B             X              Y
MAX PLOTTED     13.007        109.70        0.             99.373
MIN PLOTTED     0.            0.            0.             0.
REMARKS         VERT. SIZE.   HOR. SIZE     HOR. DIST.    VERT. DIST.
```



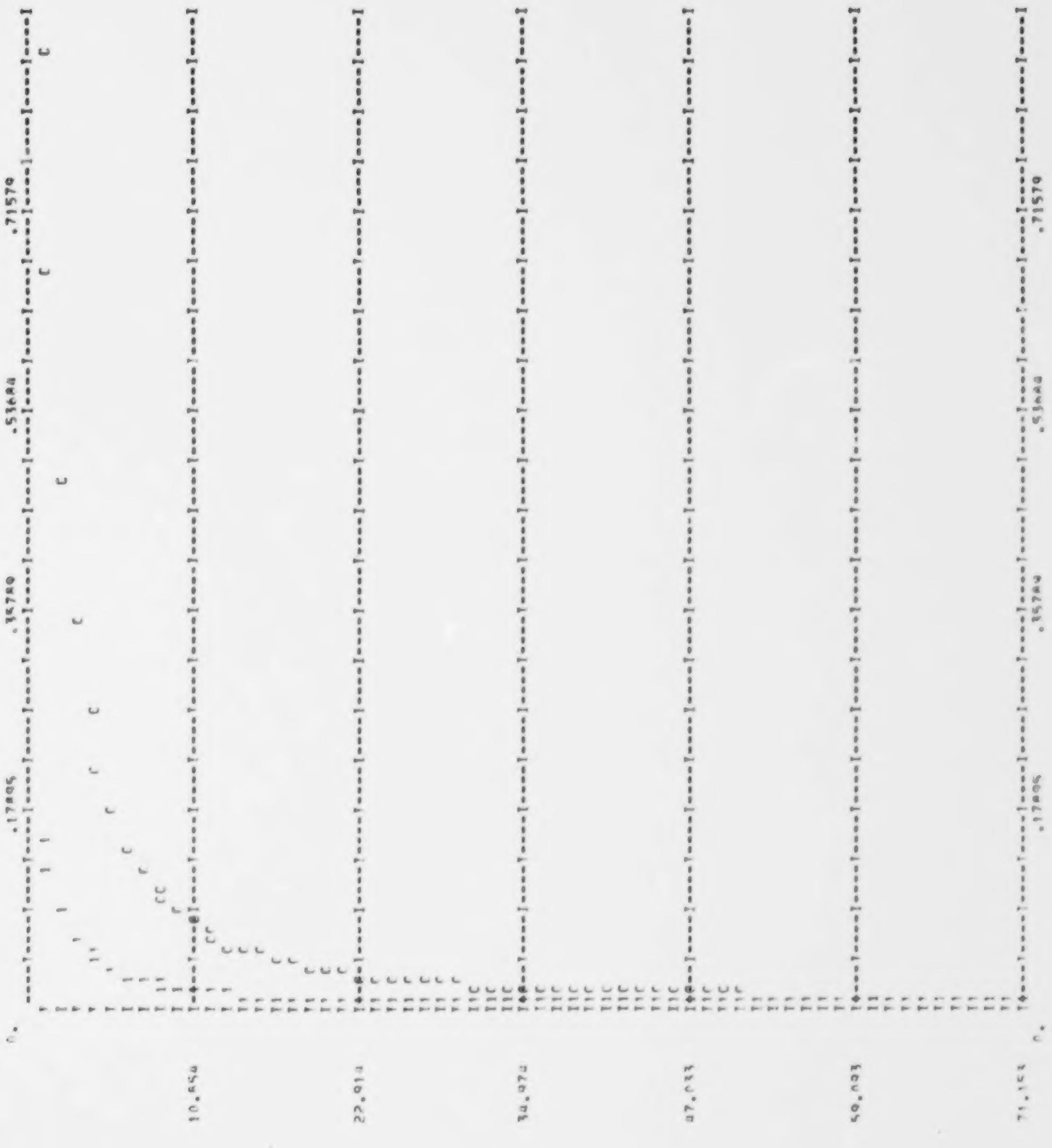
RUN D-S-6

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          71.153

                          DEPENDENT VARIABLES

                                                        X              Z
SYMBOL                Y             R              0.             0.
MAX PLOTTED       90.340         26.255         0.             0.
MIN PLOTTED       0.           0.               HOR. DIST.     HOR. DIST.
REMARKS           VERT. DIST.     RADIUS
```



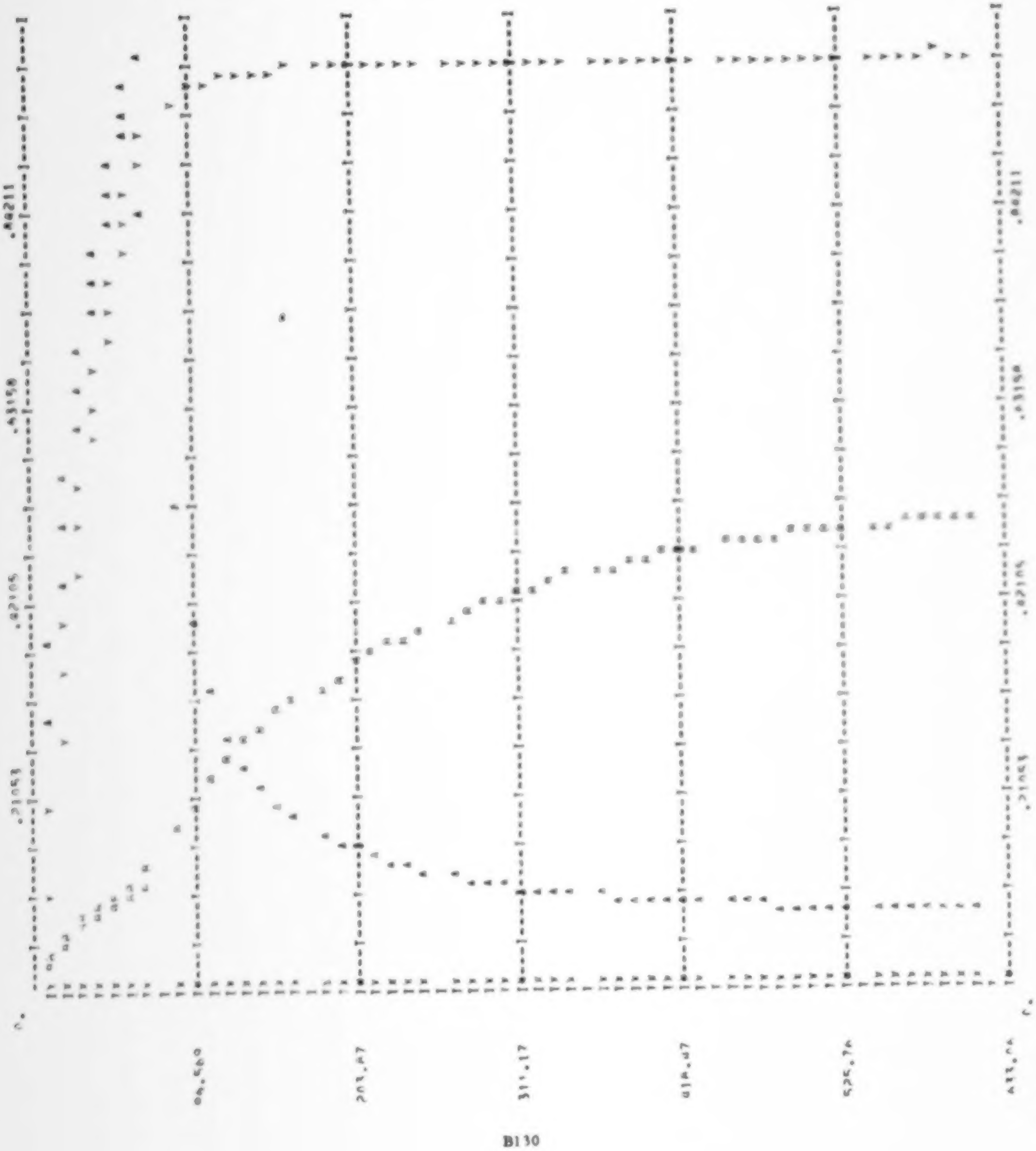
RUN D-S-6

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                0.                    71.153020
RANGE OF CONCENTRATIONS PLOTTED           0.                    .85000000
```

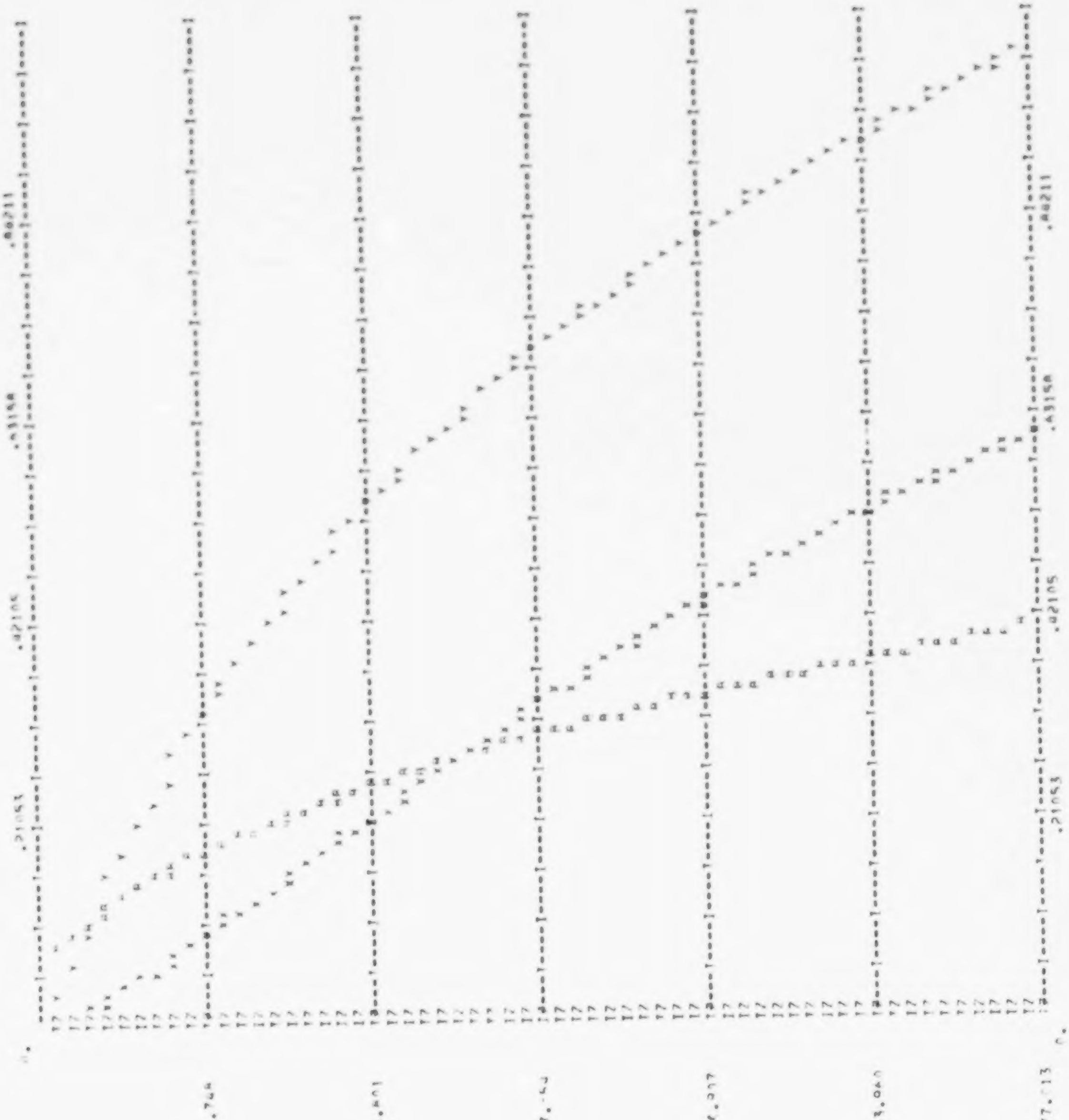


RUN D-S-6

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          633.06

                    DEPENDENT VARIABLES

SYMBOL               A            B            X             Y
MAX PLOTTED        12.882       115.58       0.            99.520
MIN PLOTTED        0.           0.           0.            0.
REMARKS           VERT. SIZE.   HOR. SIZE    HOR. DIST.    VERT. DIST.
```

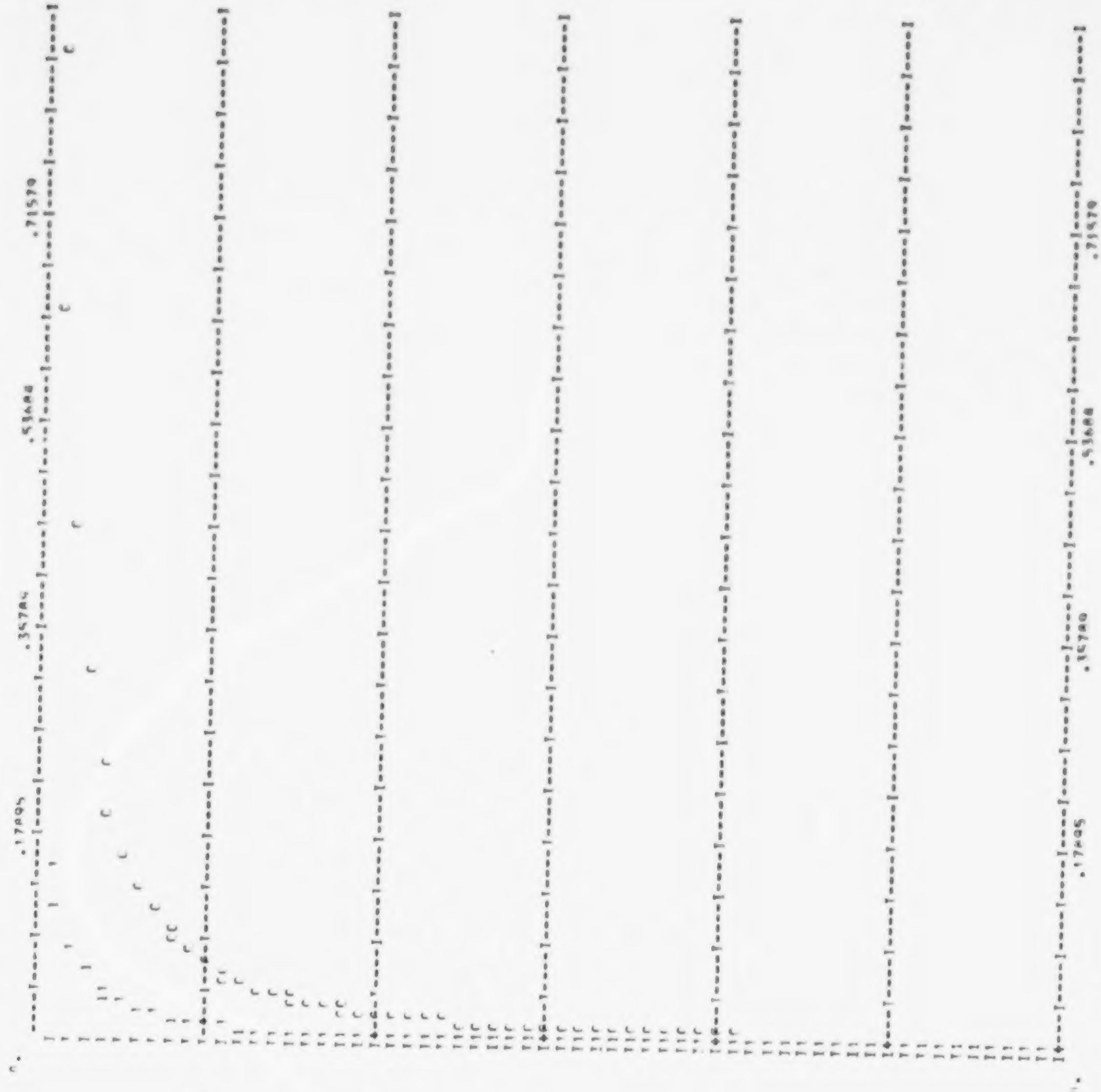


```
                                   RUN D-S-7
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          77.013

                          DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED     48.177         26.801         66.172         0.
MIN PLOTTED     0.             0.             0.             0.
STANDS FOR      VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```

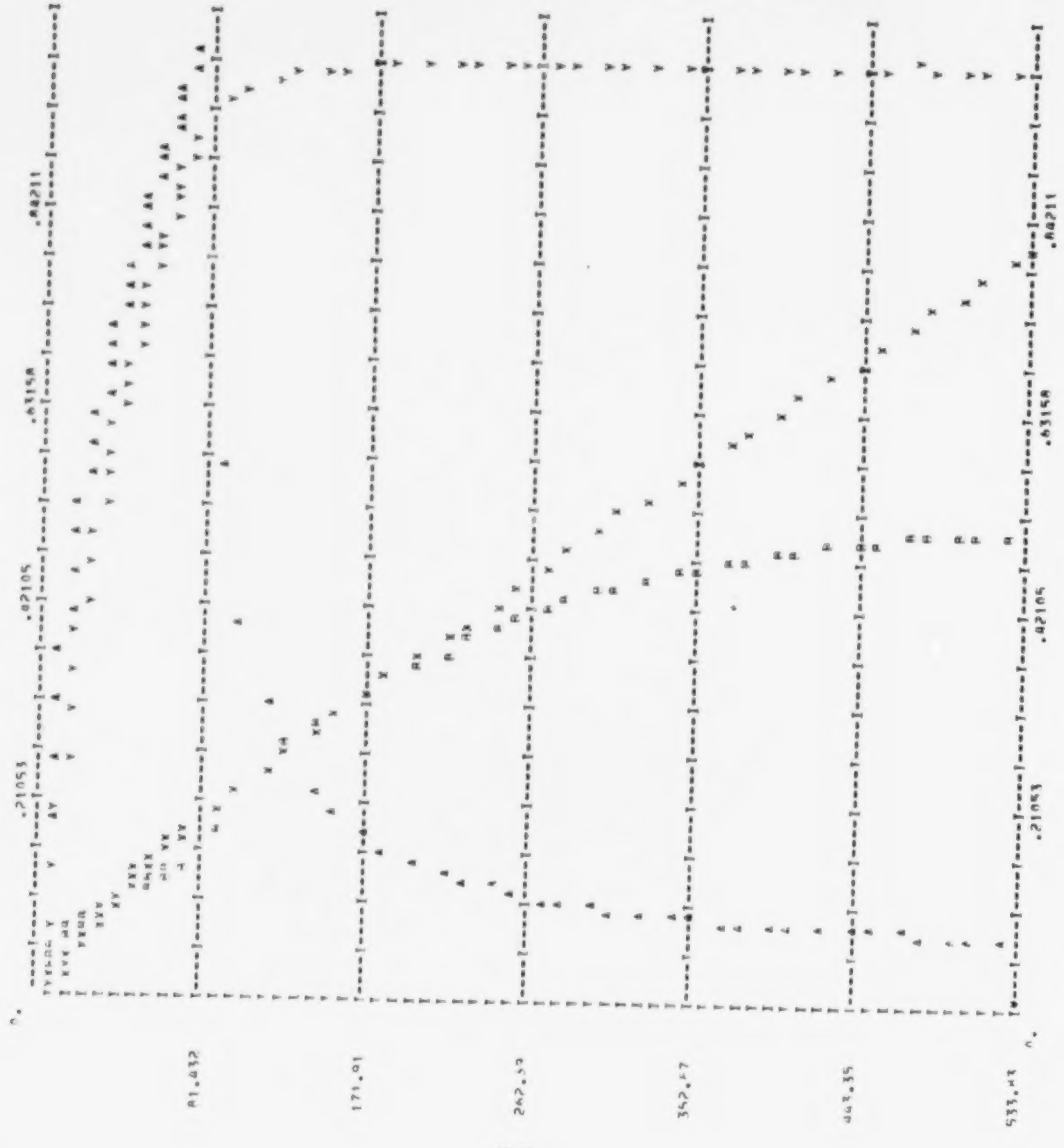


RUN D-S-7

```
GRAPH OF BASIN CONCENTRATIONS

RANGE OF X                              0.              77.012480
RANGE OF CONCENTRATIONS PLOTTED         0.              .85000000
```

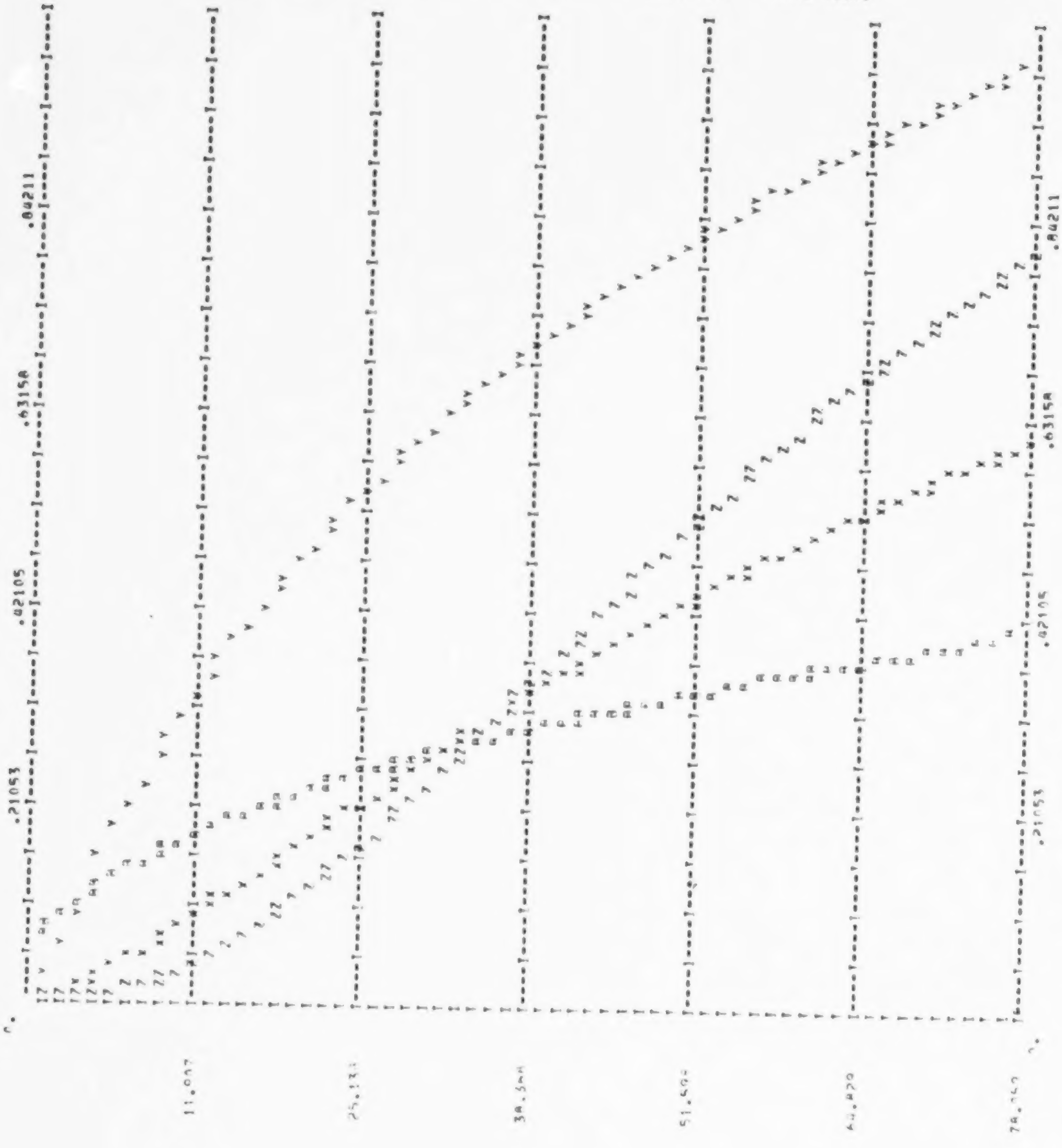


```
                                RUN D-S-7
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.            533.83

                        DEPENDENT VARIABLES

SYMBOL                A             B              X              Y
MAX PLOTTED      13.446        101.27         209.63         99.512
MIN PLOTTED      0.            0.             0.             0.
REMARKS          VERT. SIZE.   HOR. SIZE      HOR. DIST.     VERT. DIST.
```



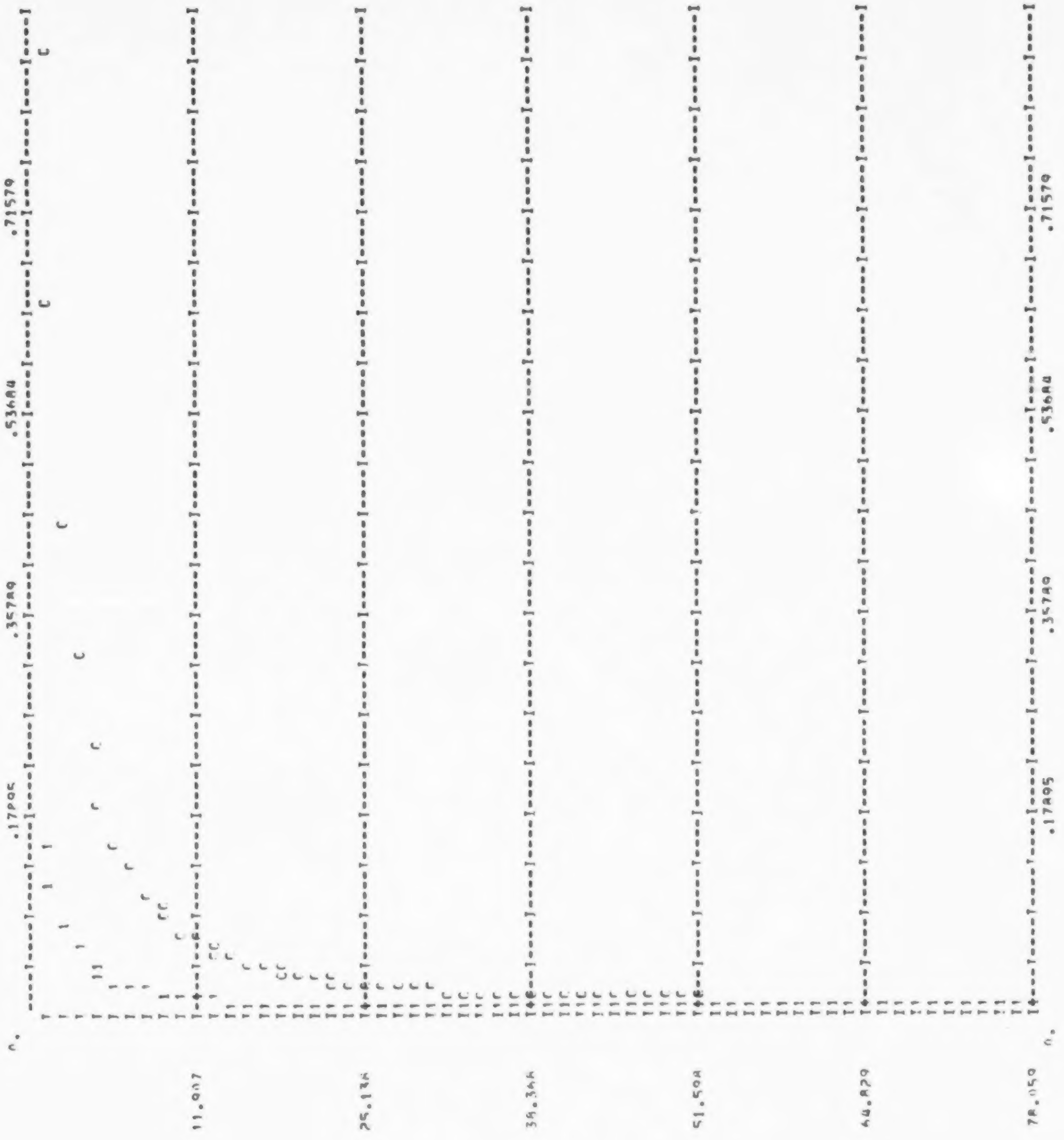
RUN D-S-8

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.            78.059

                  DEPENDENT VARIABLES

SYMBOL                  Y              R                X              Z
MAX PLOTTED       80.087          27.311          60.845         85.458
MIN PLOTTED       0.              0.              0.             0.
REMARKS           VERT. DIST.      RADIUS         HOR. DIST.     HOR. DIST.
```

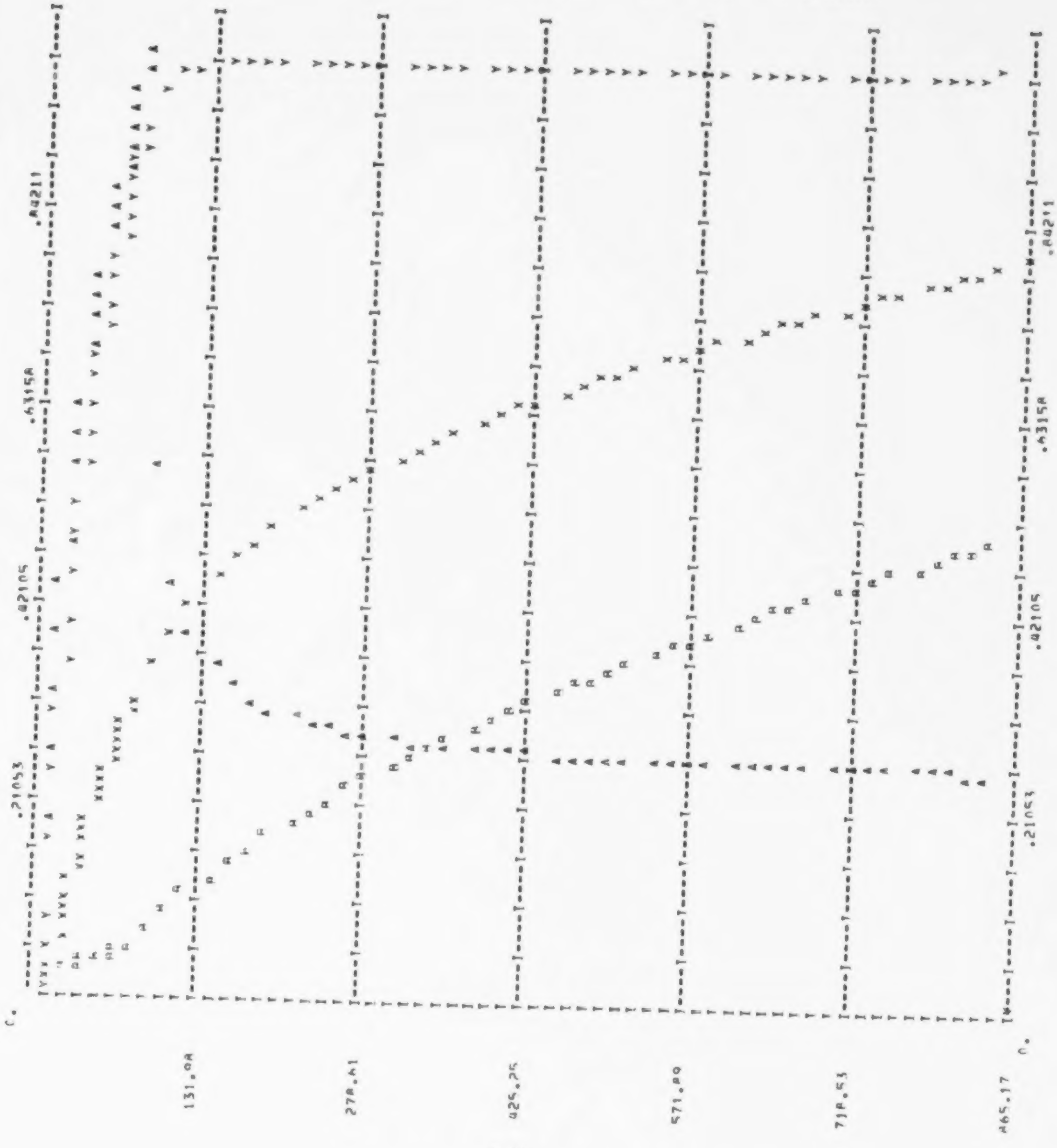


RUN D-S-8

```
GRAPH OF WASTE  CONCENTRATIONS
                                                0.                      78.059048
RANGE OF X                                                              .85000000
RANGE OF CONCENTRATIONS PLOTTED                 0.
```



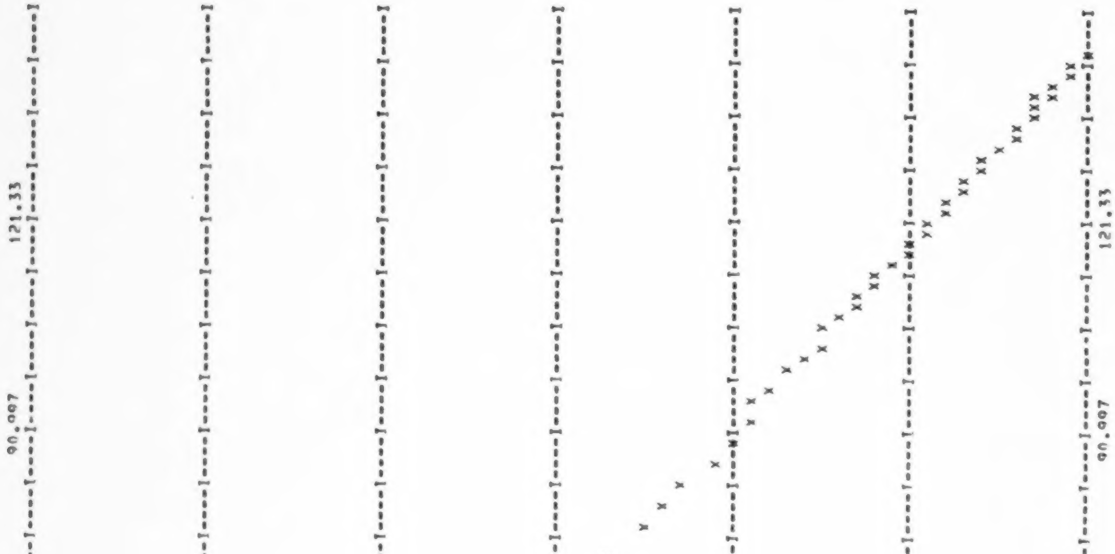
```
                              RUN D-S-8
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          865.17

                         DEPENDENT VARIABLES

SYMBOL                  A             B              X              Y
MAX PLOTTED       13.656        297.73         168.49         97.646
MIN PLOTTED      0.            0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



RUN D-S-8

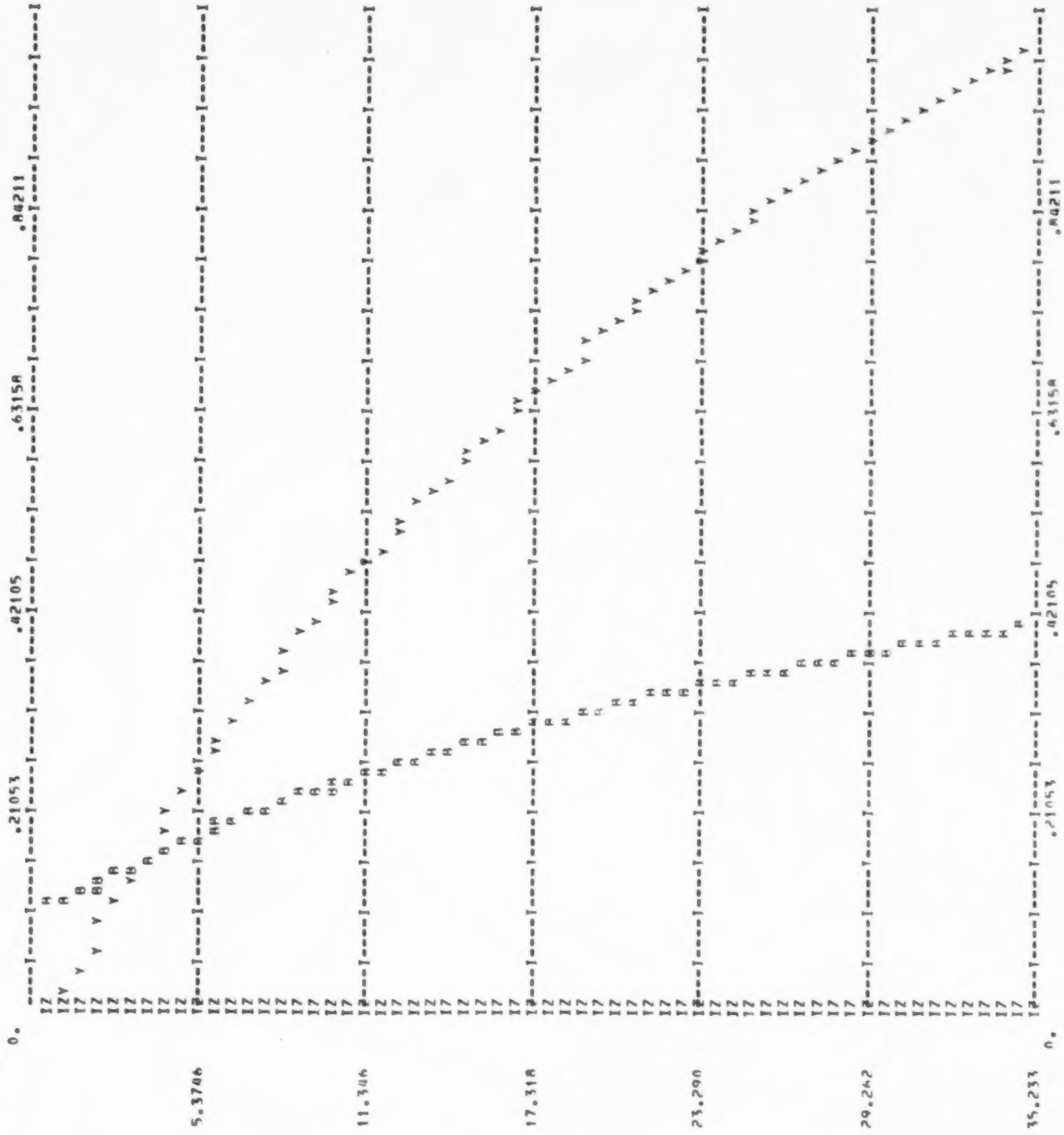
GRAPH OF X VS Z

RANGE OF X   0.   168.48772
RANGE OF Z   0.   144.07884



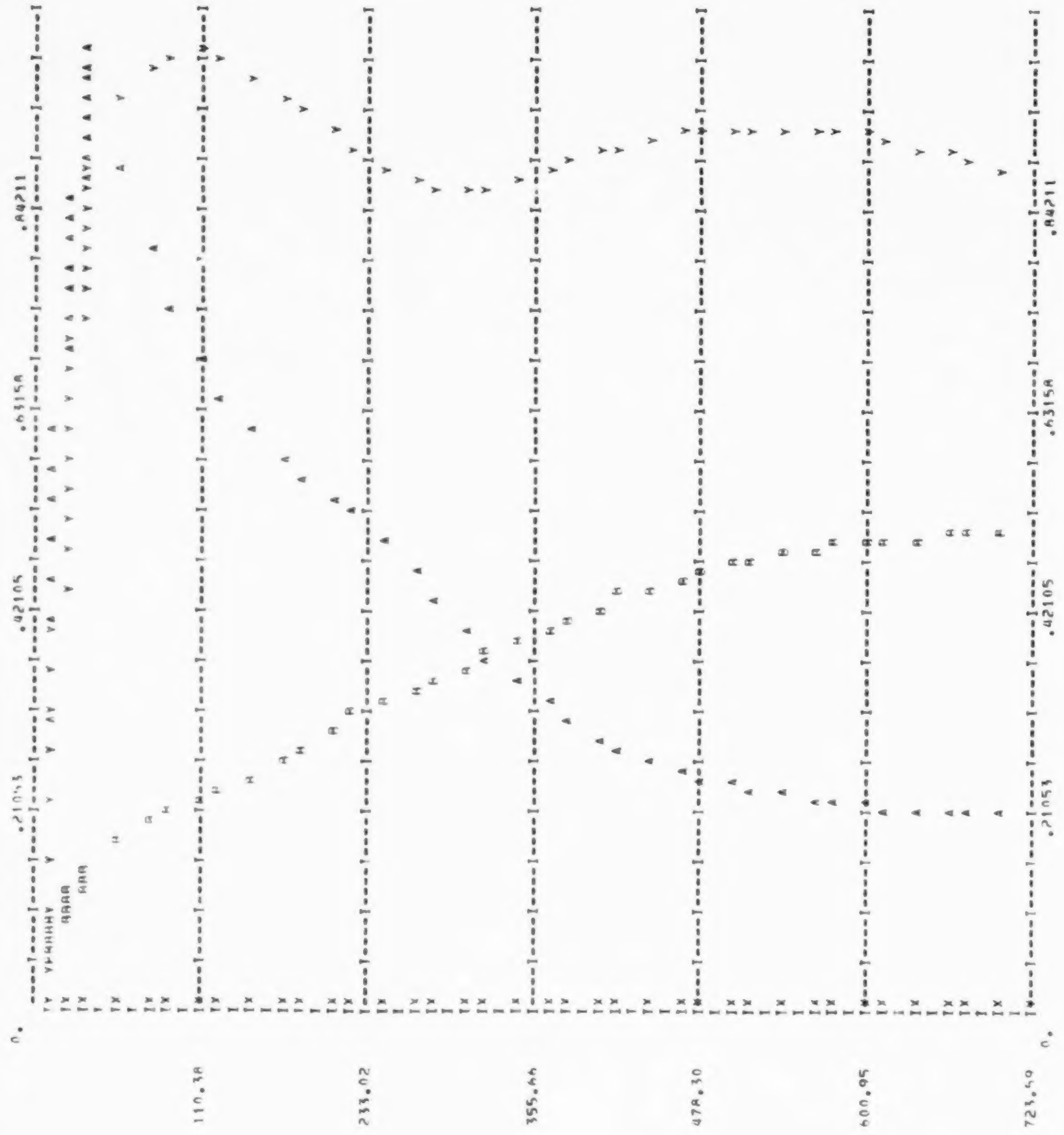
RUN D-S-9

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          35.233

                         DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED     57.894         18.605         0.             0.
MIN PLOTTED    0.             0.             0.             0.
REMARKS        VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



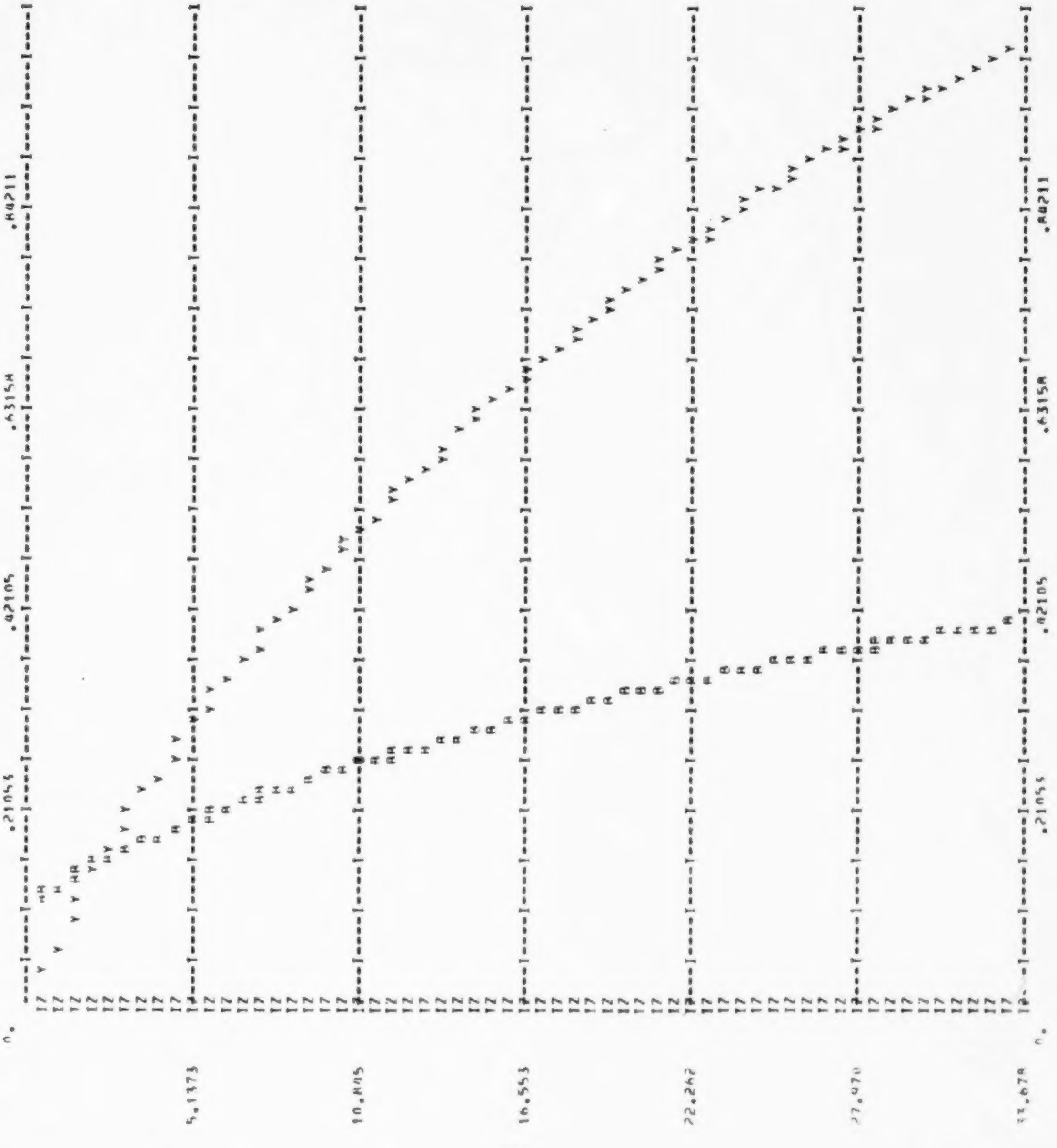
RUN D-S-9

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          723.59

                         DEPENDENT VARIABLES

SYMBOL                A              H            X               Y
MAX PLOTTED      9.3024         65.699        0.              66.021
MIN PLOTTED      0.             0.            0.              0.
REMARKS          VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



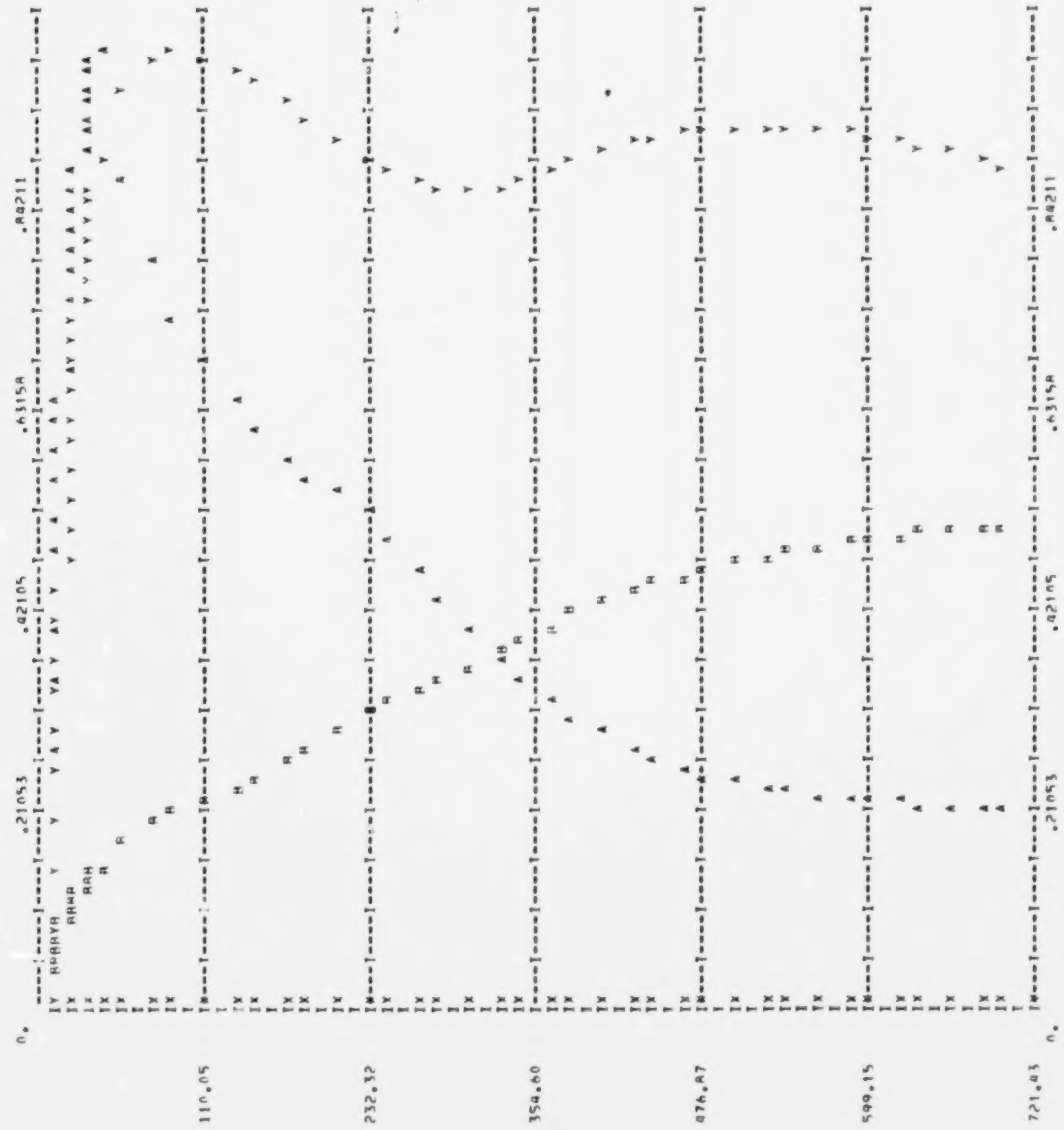
RUN D-S-10

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          33.678

                        DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED     57.636         18.544         0.            0.
MIN PLOTTED     0.             0.             0.            0.
REMARKS         VERT. DIST.    RADIUS        HOR. DIST.    HOR. DIST.
```



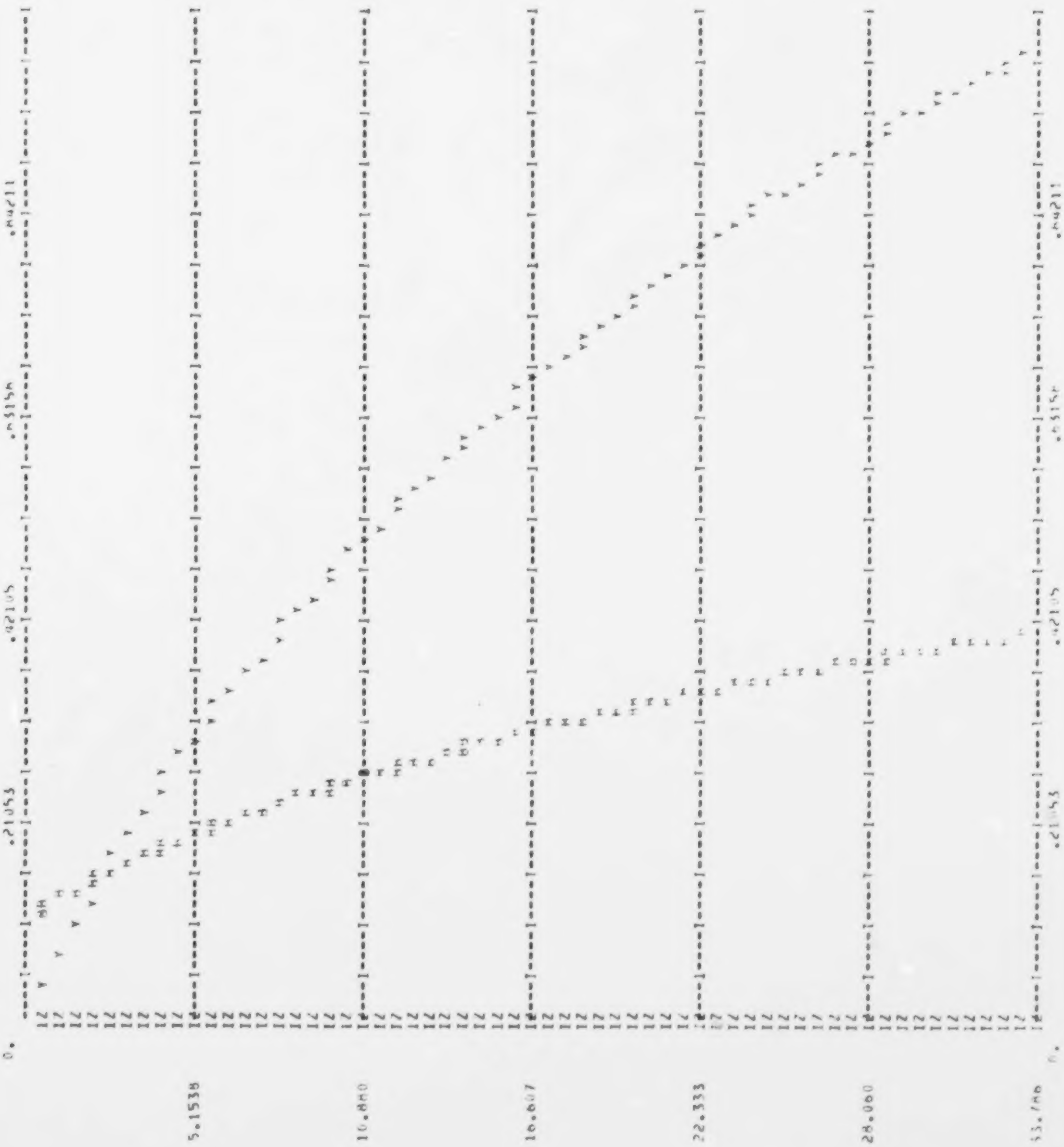
RUN D-S-10

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          721.43

                      DEPENDENT VARIABLES

SYMBOL              A              B             X               Y
MAX PLOTTED     9.2100         65.705        0.             66.035
MIN PLOTTED    0.             0.            0.             0.
REMARKS        VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```

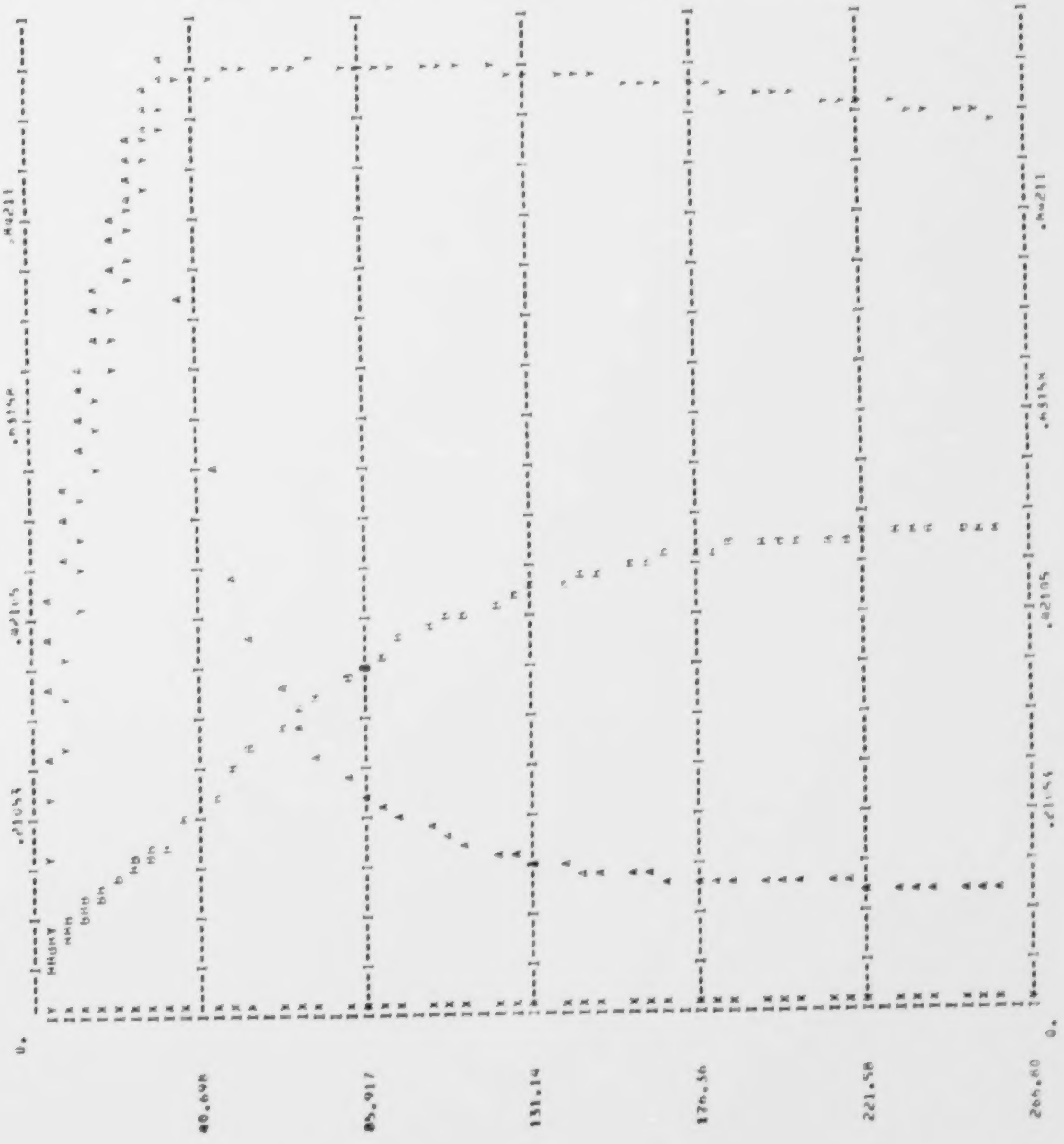


RUN D-S-11

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.          33.786

                     DEPENDENT VARIABLES

SYMBOL              Y             R             X              Z
MAX PLOTTED     57.885        18.603        0.            0.
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. DIST.    RADIUS        HOR. DIST.    HOR. DIST.
```

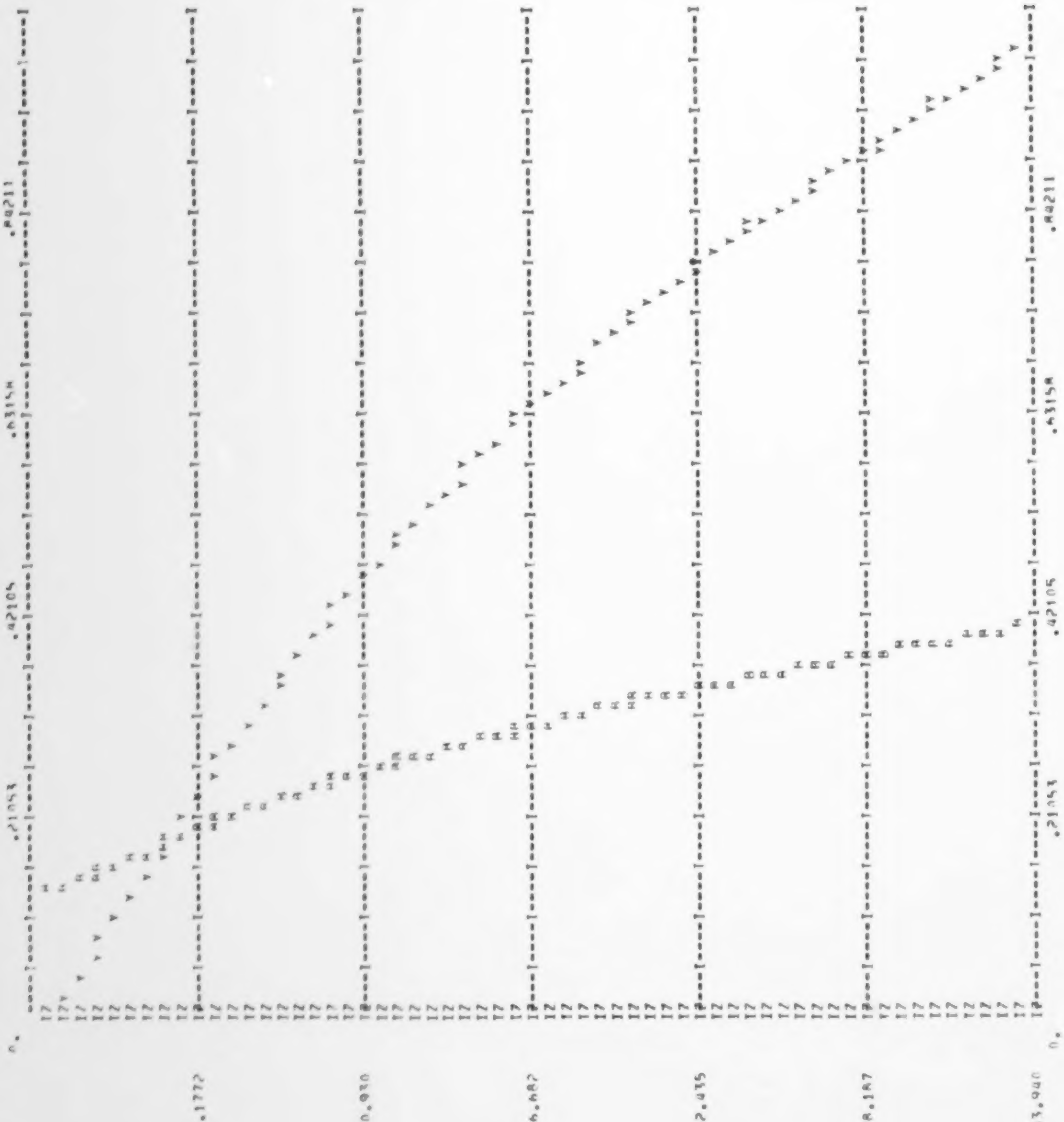


```
                         RUN D-S-11
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          266.80

                    DEPENDENT VARIABLES

SYMBOL               A              H             X              Y
MAX PLOTTED      9.3015         53.452        0.            60.569
MIN PLOTTED      0.             0.            0.            0.
REMARKS          VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



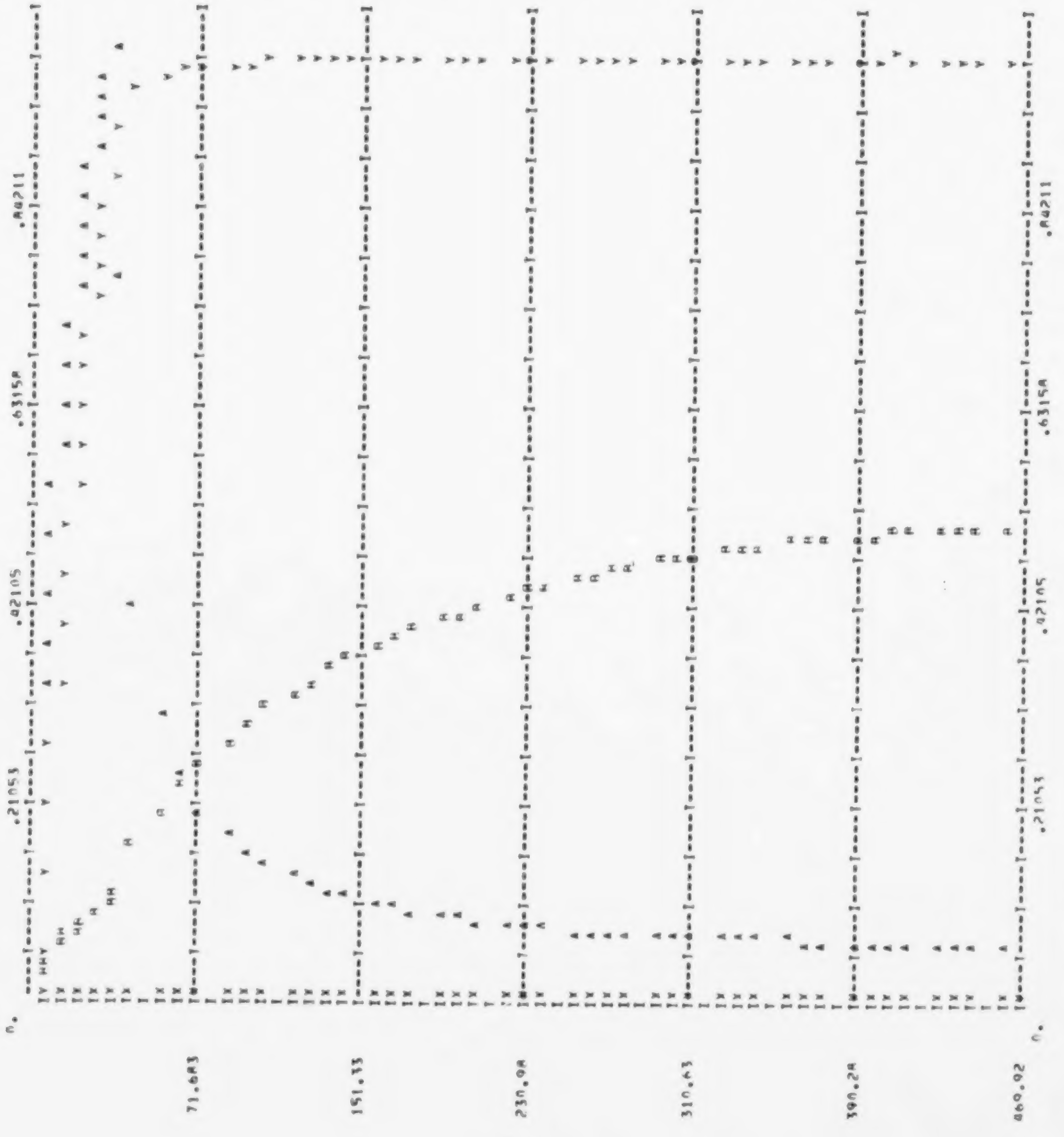
RUN D-S-12

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.          33.940

                      DEPENDENT VARIABLES

SYMBOL              Y             R             X             Z
MAX PLOTTED     88.778        30.863        0.            0.
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. DIST.   RADIUS        HOR. DIST.    HOR. DIST.
```



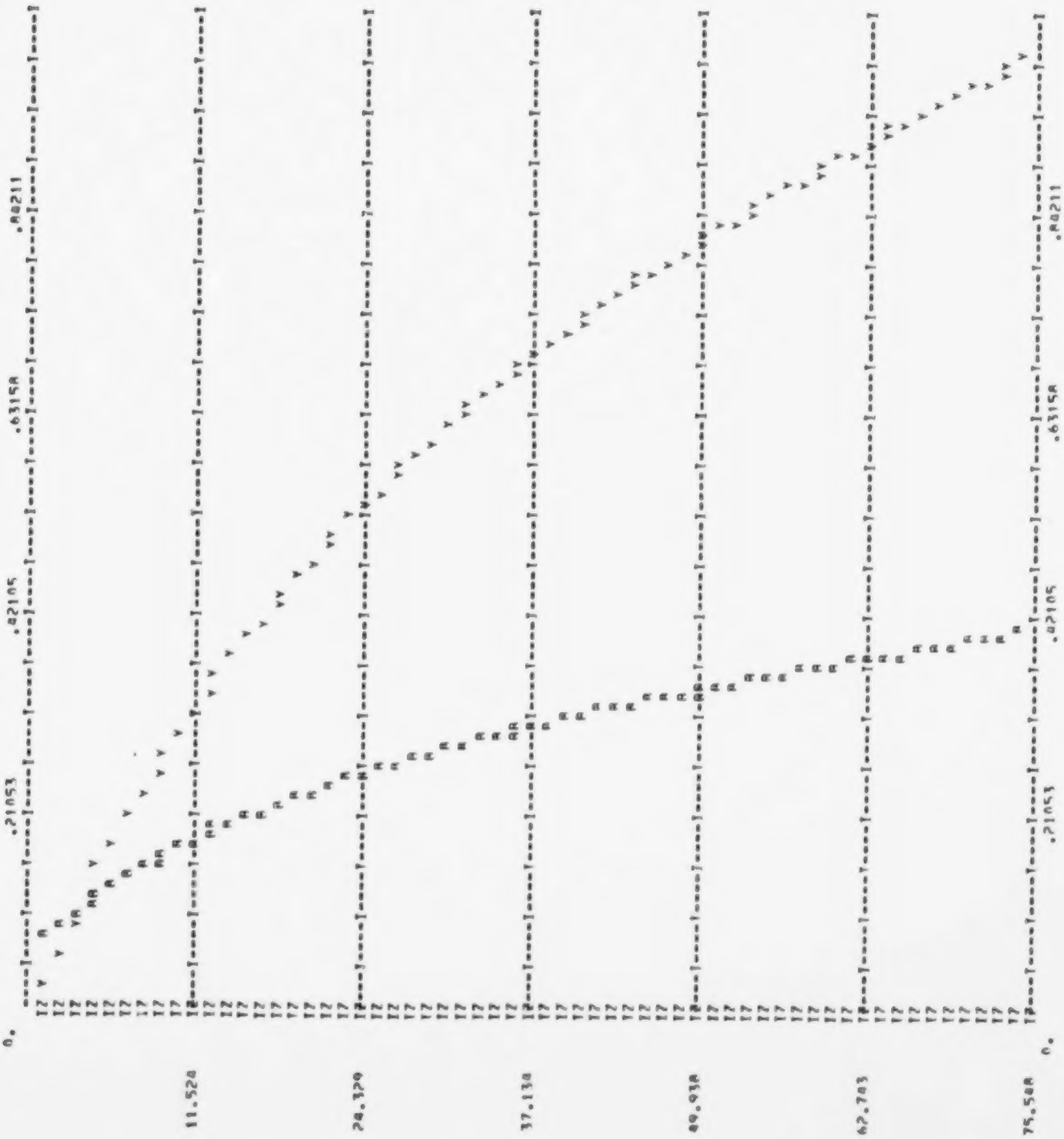
RUN D-S-12

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          469.92

                        DEPENDENT VARIABLES

SYMBOL              A              B            X              Y
MAX PLOTTED     15.169         159.44        0.             99.661
MIN PLOTTED     0.             0.            0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



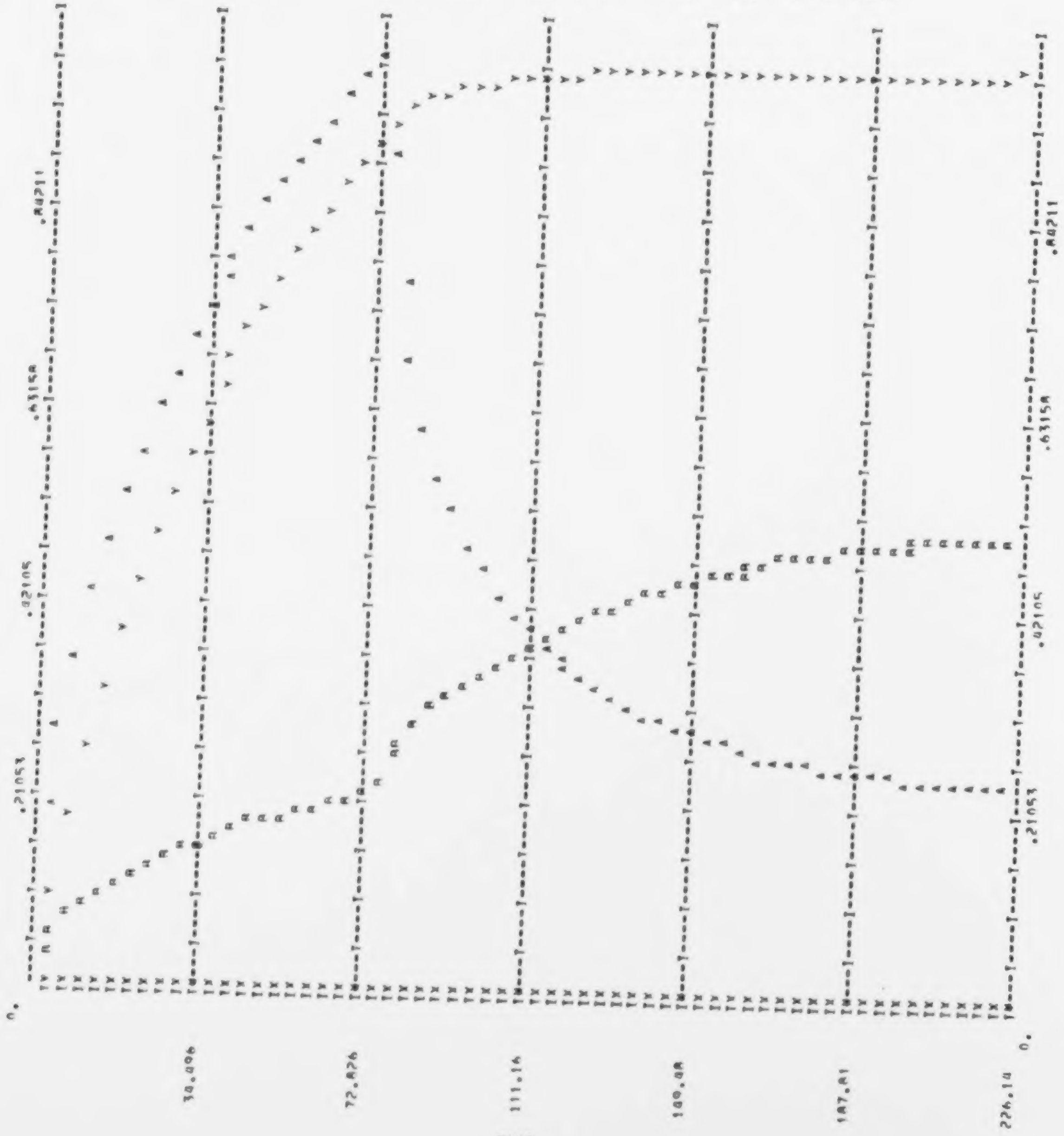
RUN D-S-13

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.          75.548

                         DEPENDENT VARIABLES

SYMBOL               Y            R            X            Z
MAX PLOTTED     90.391       26.282       0.           0.
MIN PLOTTED     0.           0.           0.           0.
REMARKS         VERT. DIST.   RADIUS      HOR. DIST.   HOR. DIST.
```



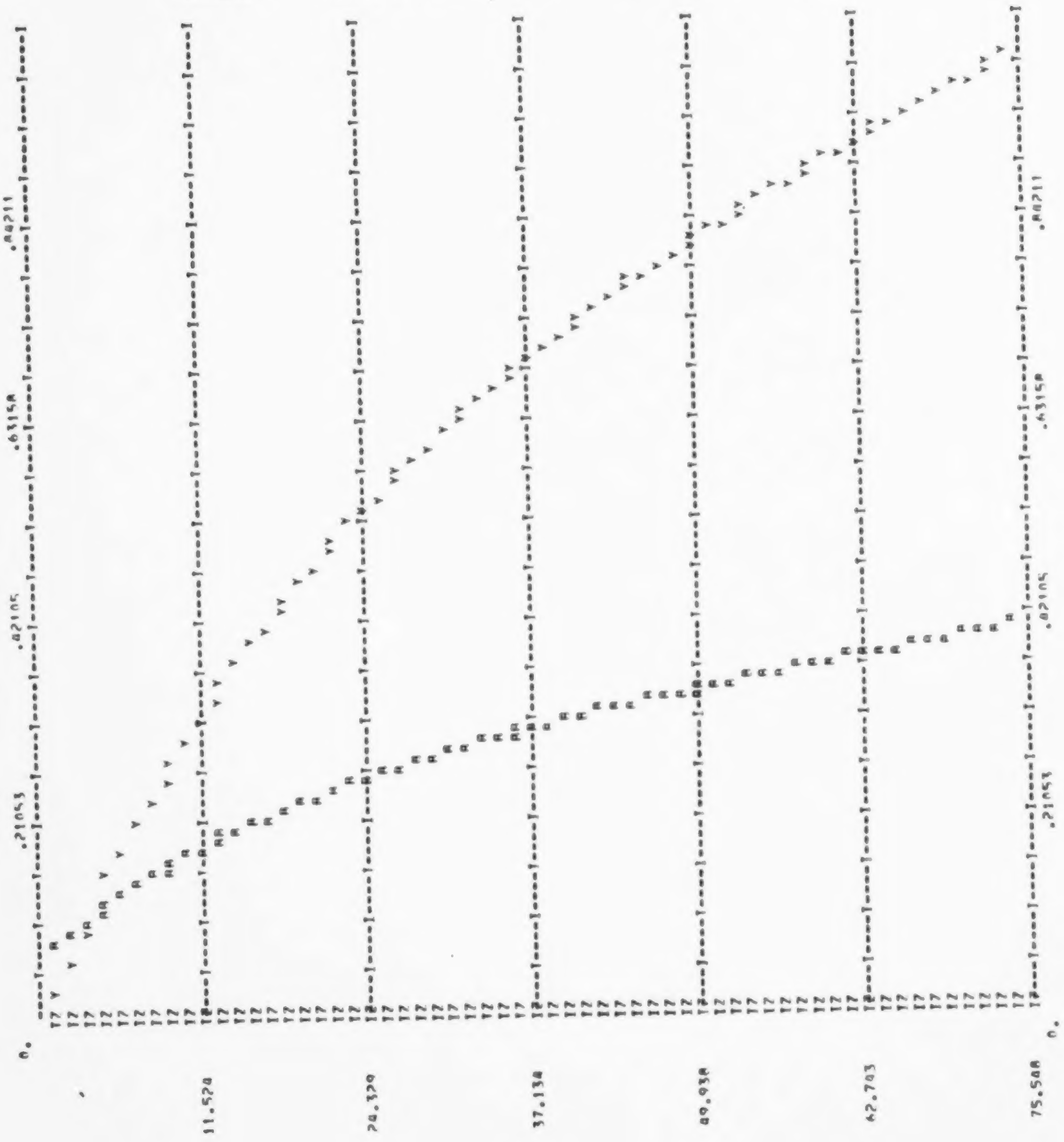
RUN D-S-13

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          226.14

                    DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     13.007         61.216         0.              97.930
MIN PLOTTED     0.             0.             0.              0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.      VERT. DIST.
```



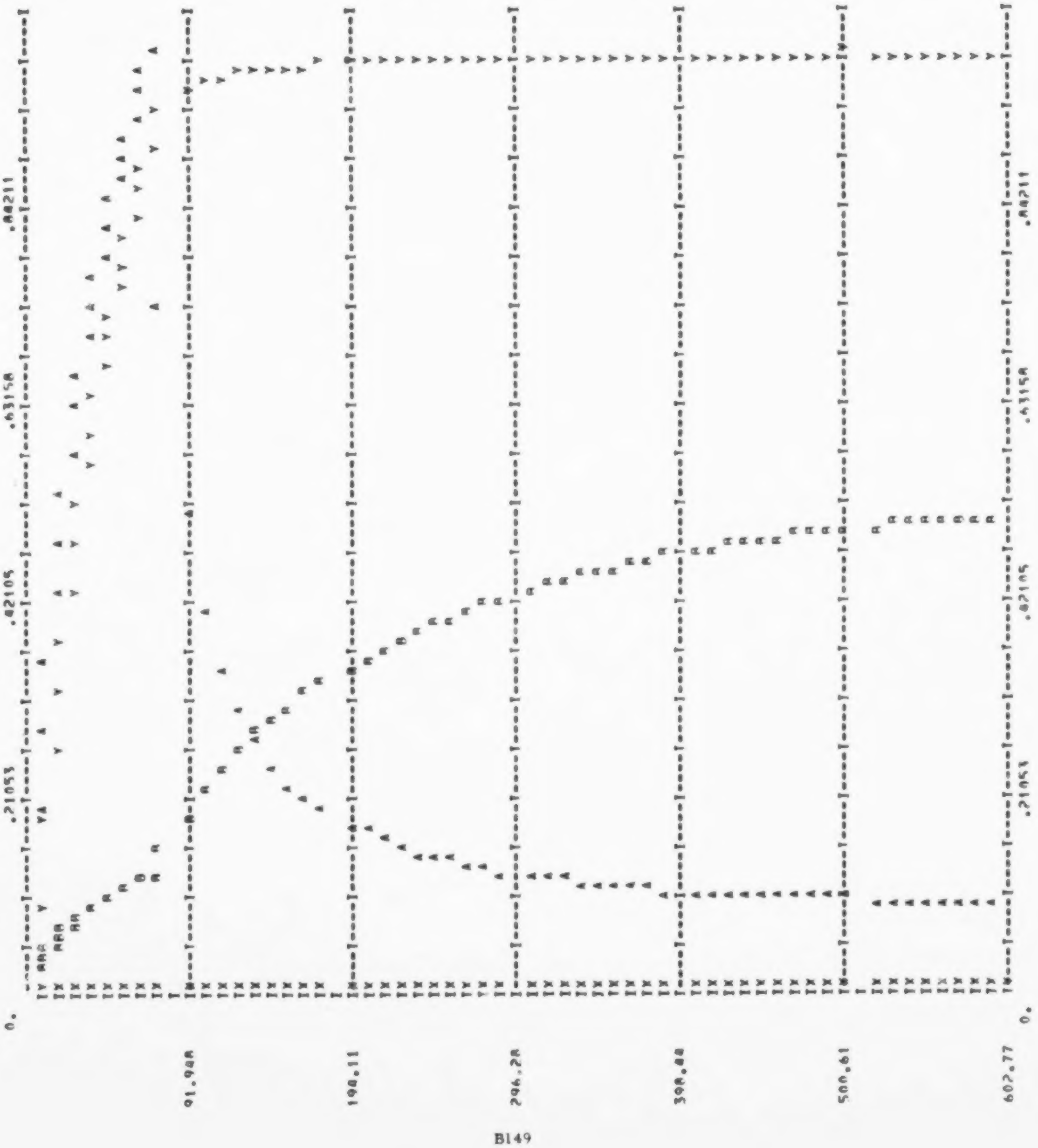
RUN D-S-14

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.            75.548

                       DEPENDENT VARIABLES

SYMBOL               Y             R              X             Z
MAX PLOTTED      90.391        26.282         0.            0.
MIN PLOTTED      0.            0.             0.            0.
REMARKS          VERT. DIST.    RADIUS         HOR. DIST.    HOR. DIST.
```



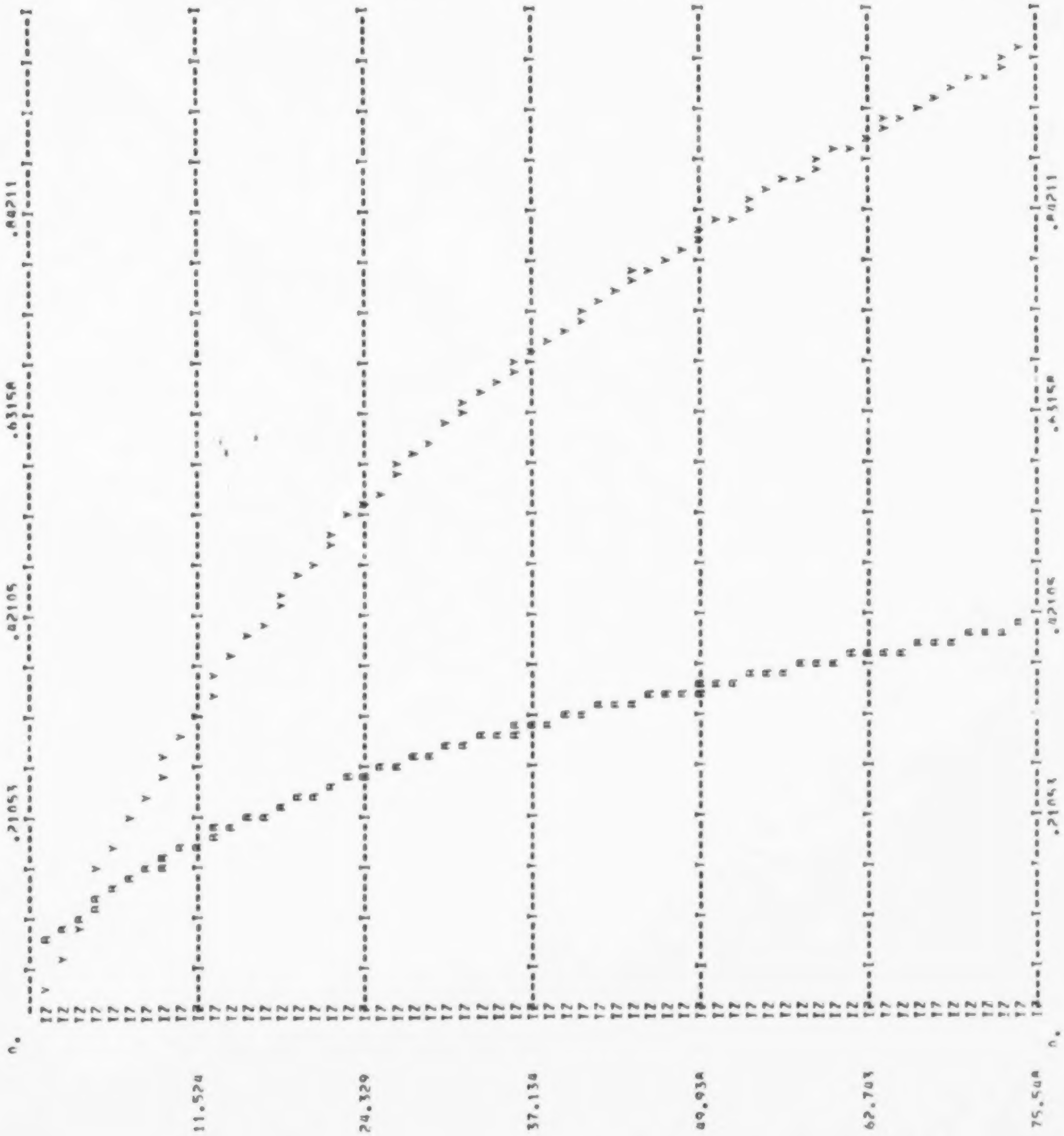
RUN D-S-14

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          602.77

                       DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     13.007         104.91         0.             99.306
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



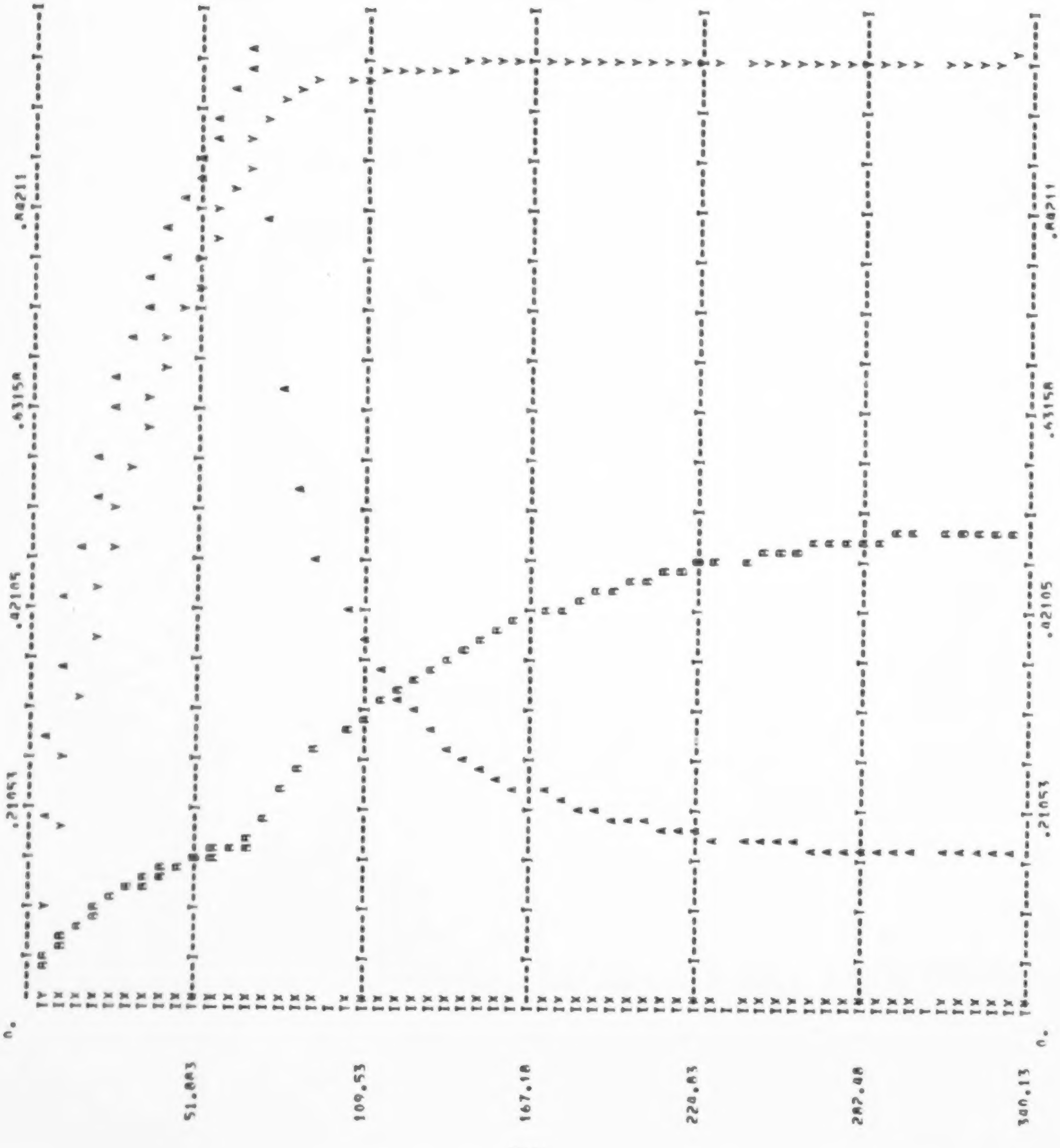
RUN D-S-15

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           75.548

                         DEPENDENT VARIABLES

SYMBOL              Y              R              X              Z
MAX PLOTTED     90.391         26.242         0.             0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         HOR. DIST.     HOR. DIST.
```



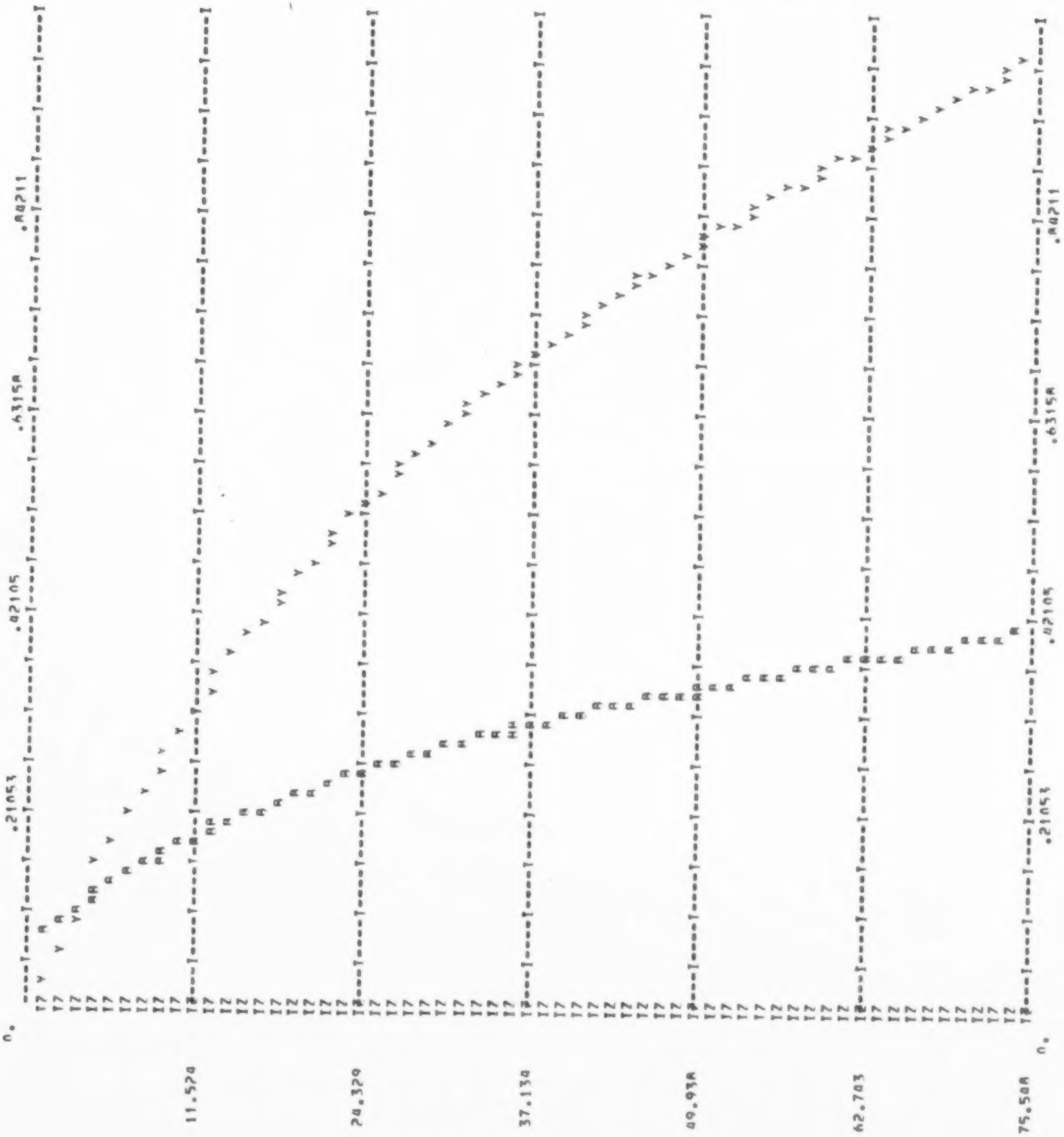
RUN D-S-15

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          340.13

                    DEPENDENT VARIABLES

SYMBOL            A             B             X              Y
MAX PLOTTED    13.007        76.485        0.             98.673
MIN PLOTTED    0.            0.            0.             0.
REMARKS        VERT. SIZE.   HOR. SIZE     HOR. DIST.     VERT. DIST.
```

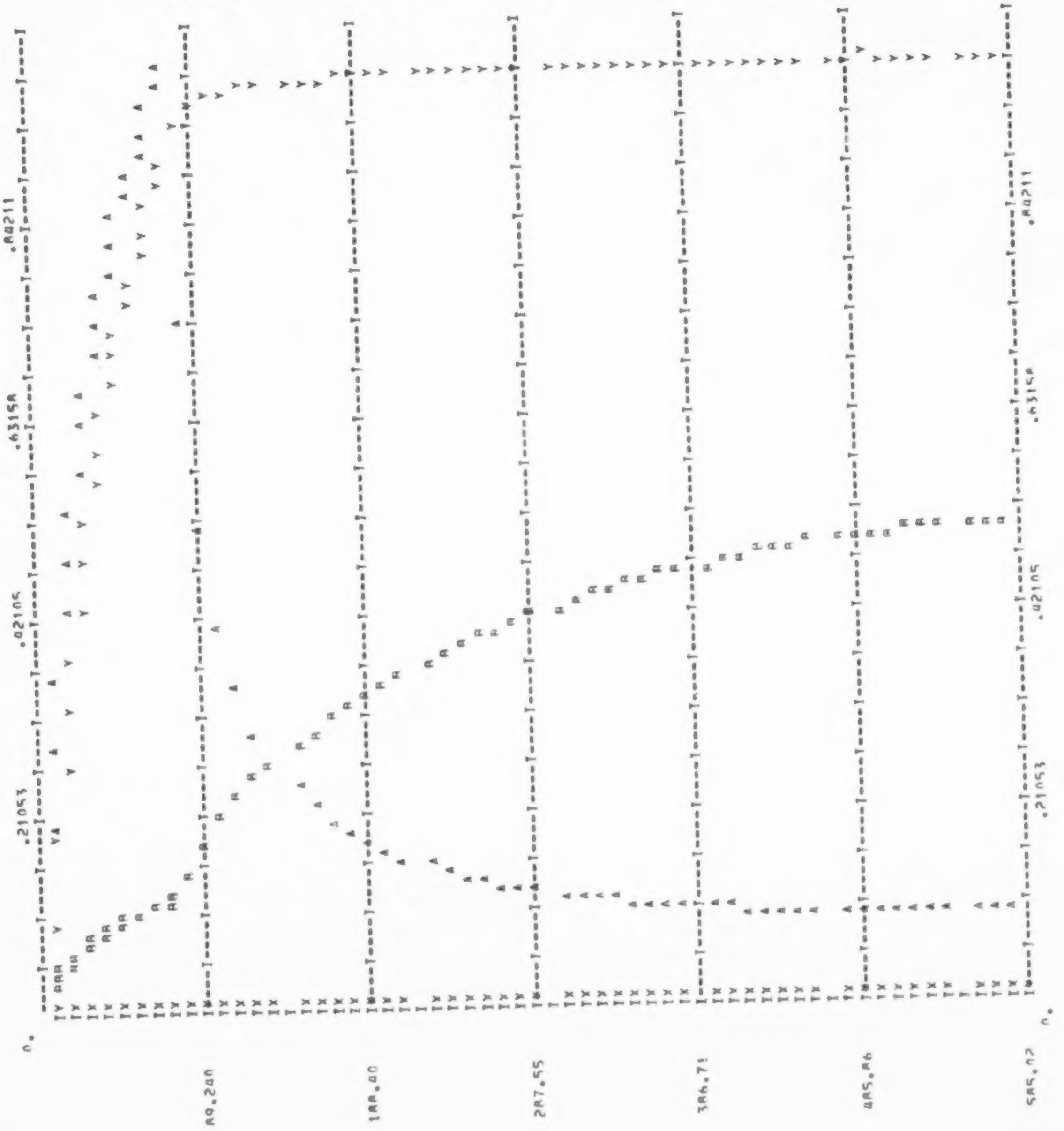


RUN D-S-16

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.            75.548

                        DEPENDENT VARIABLES

SYMBOL                 Y               R               X               Z
MAX PLOTTED       90.391          26.842          0.              0.
MIN PLOTTED      0.             0.               0.              0.
REMARKS          VERT. DIST.     RADIUS          HOR. DIST.      HOR. DIST.
```

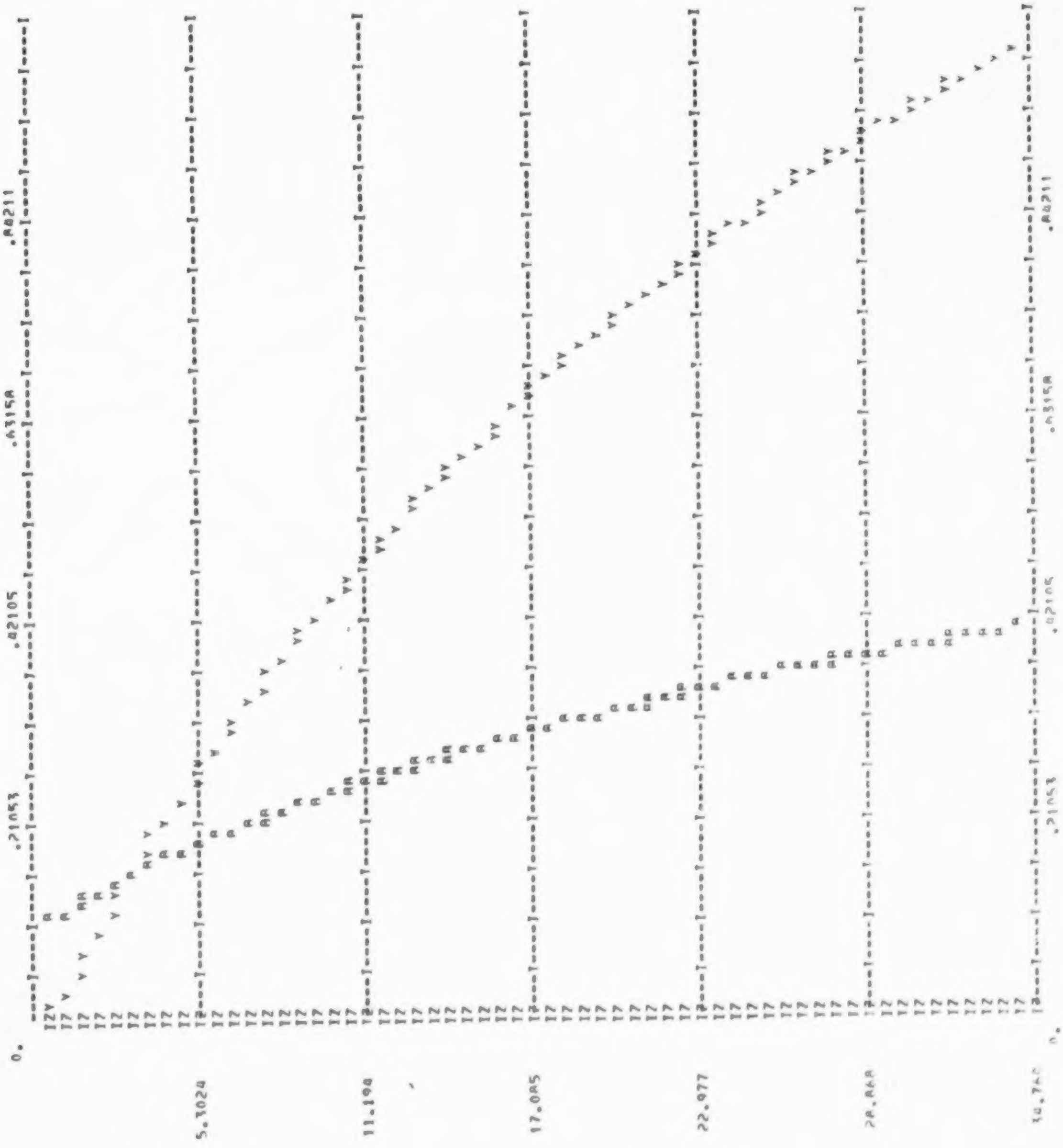


```
                                  RUN D-S-16
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          585.02

                             DEPENDENT VARIABLES

SYMBOL               A              B              X              Y
MAX PLOTTED      13.007         110.20         0.             99.380
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



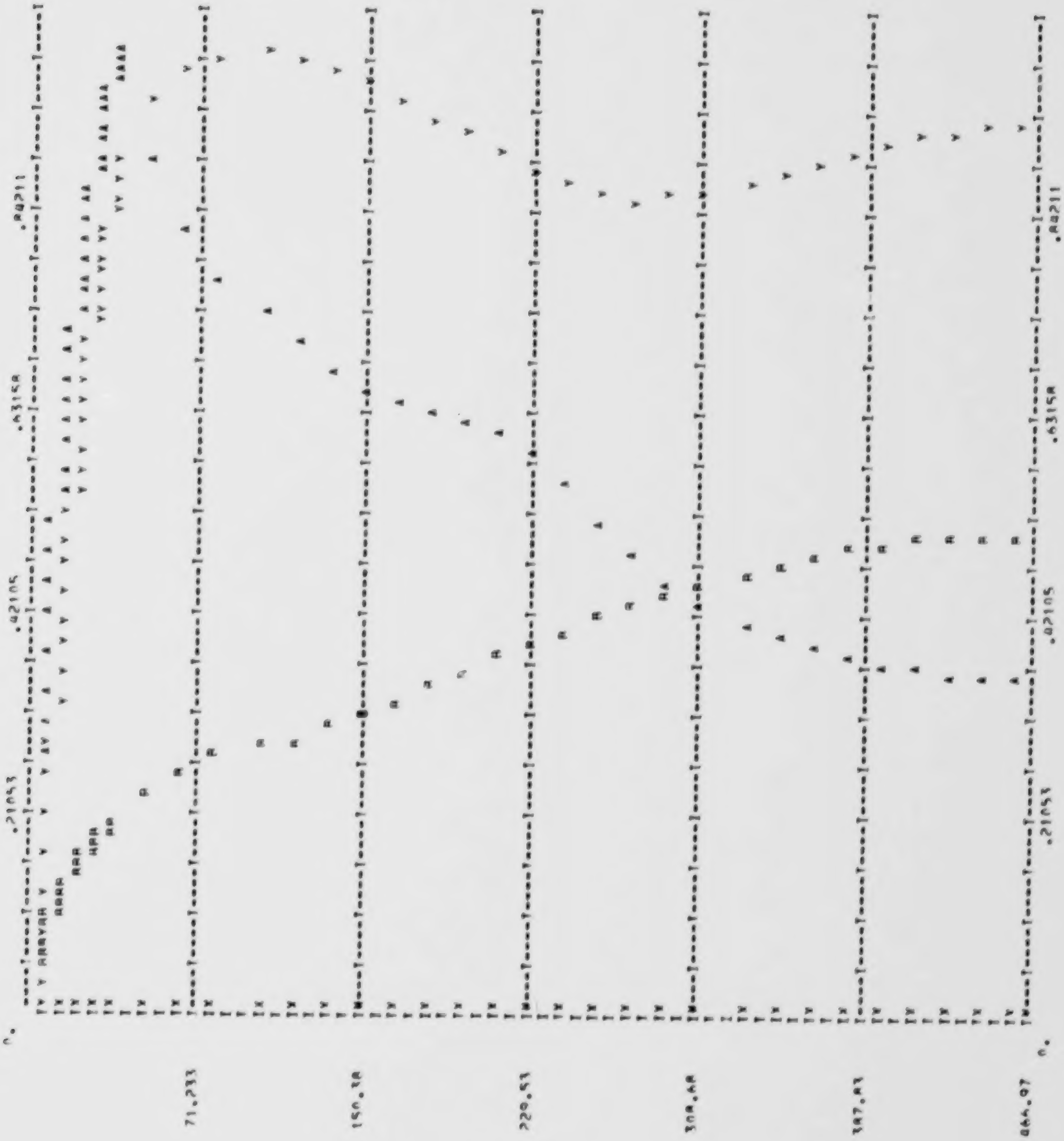
RUN D-S-17

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          34.760

                    DEPENDENT VARIABLES

SYMBOL              Y             R            X            Z
MAX PLOTTED      57.636        18.500       0.           0.
MIN PLOTTED     0.           0.            0.           0.
REMARKS         VERT. DIST.    RADIUS       HOR. DIST.   HOR. DIST.
```



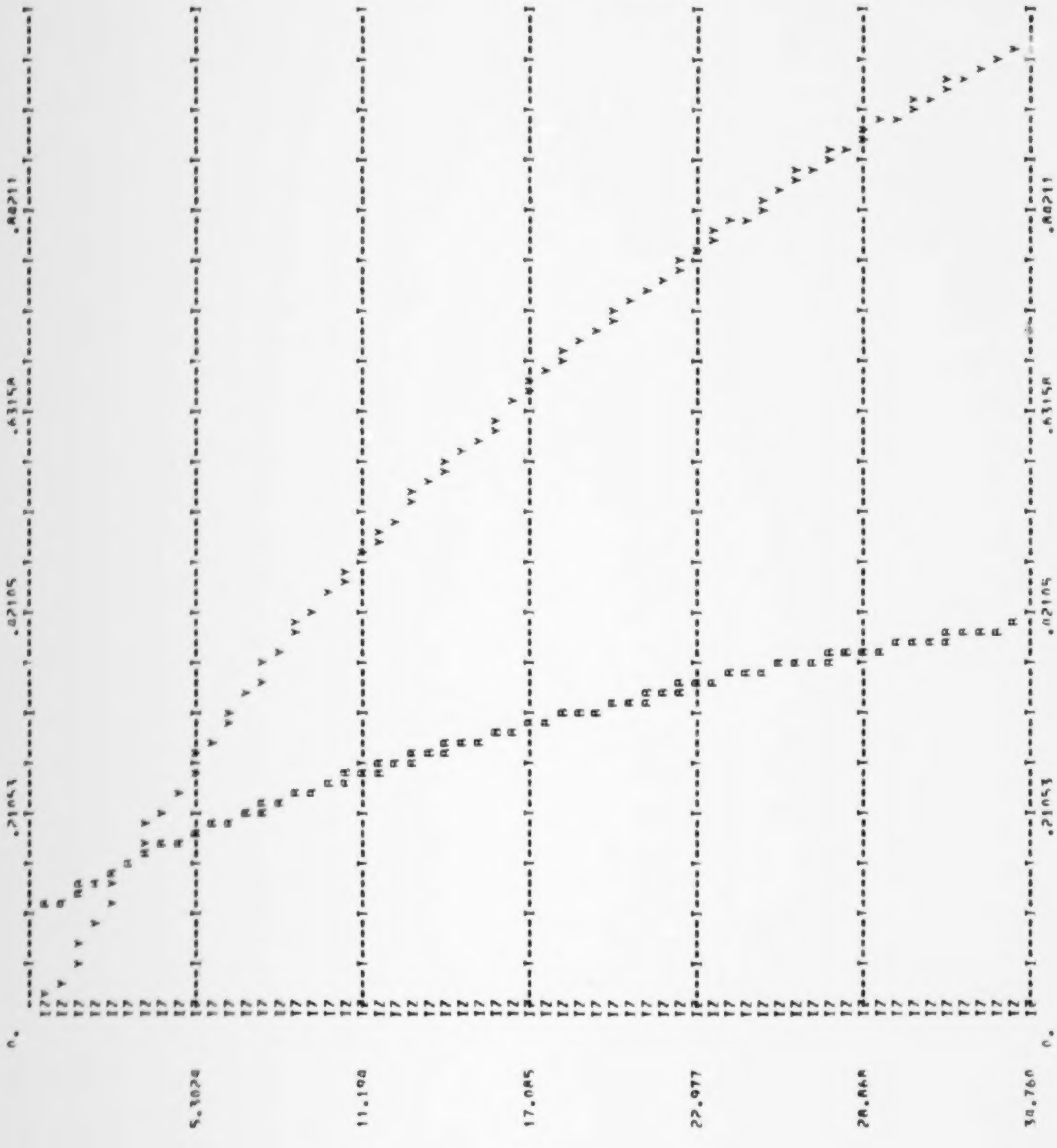
RUN D-S-17

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.            466.97

                      DEPENDENT VARIABLES

SYMBOL              A              B              X              Y
MAX PLOTTED     9.2110         48.887         0.             66.117
MIN PLOTTED    0.             0.             0.             0.
REMARKS        VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



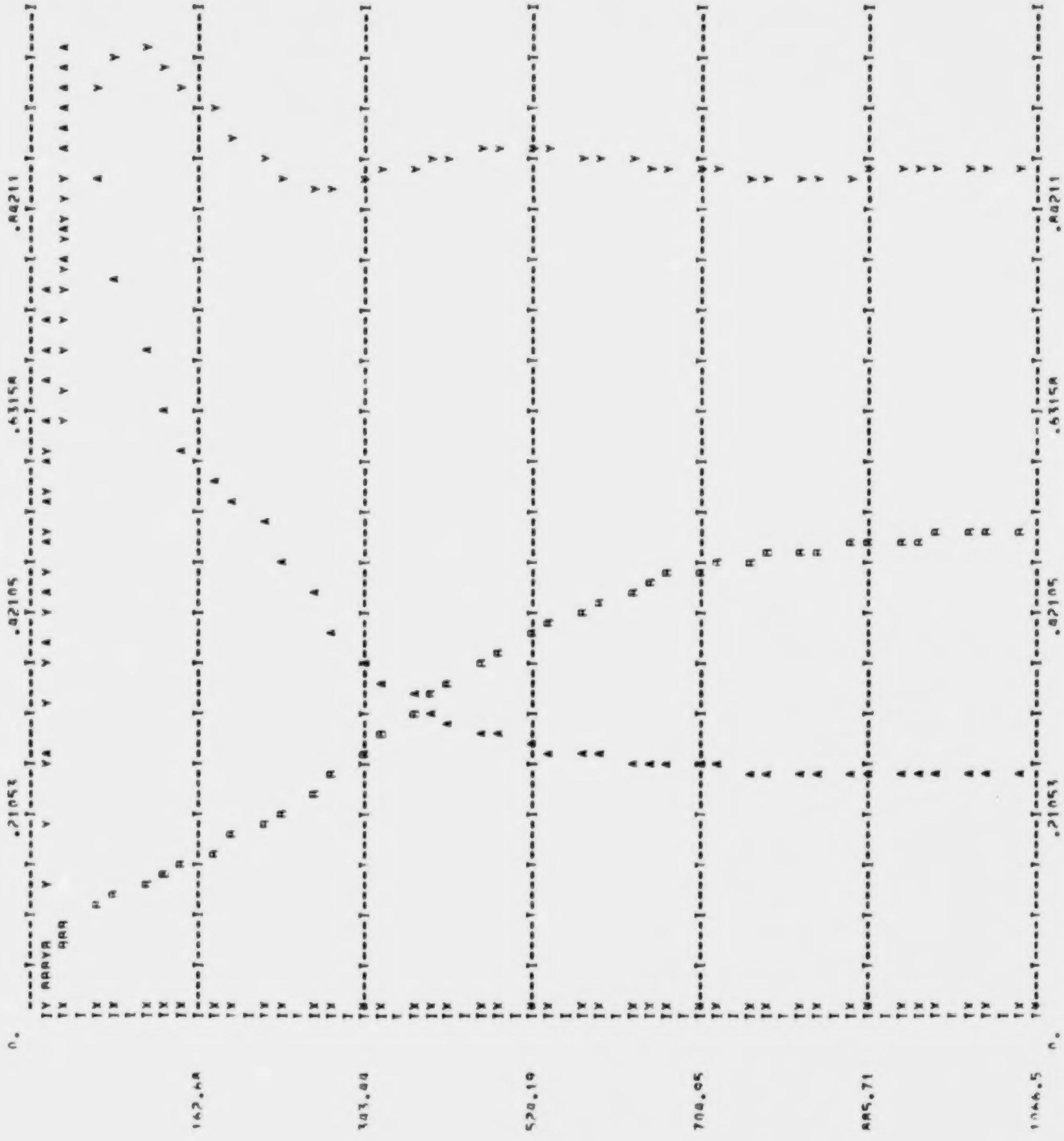
RUN D-S-18

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          34.760

                    DEPENDENT VARIABLES

SYMBOL              V              R             X            Z
MAX PLOTTED     57.636         18.544         0.           0.
MIN PLOTTED     0.             0.             0.           0.
REMARKS         VERT. DIST.    RADIUS        HOR. DIST.   HOR. DIST.
```



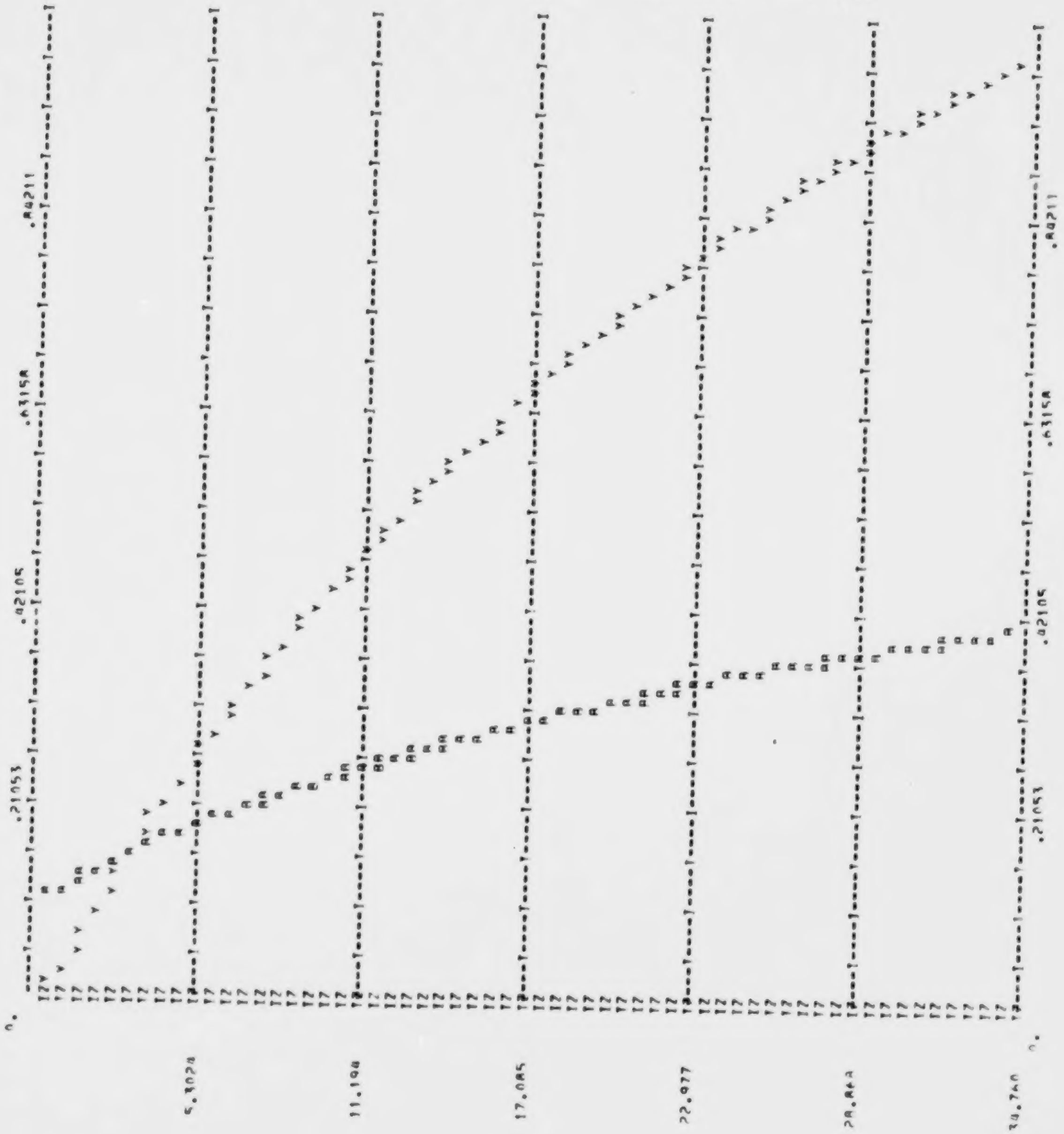
RUN D-S-18

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          1066.5

                         DEPENDENT VARIABLES

SYMBOL              A             B            X              Y
MAX PLOTTED      9.2722        106.52        0.            66.043
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.   VERT. DIST.
```



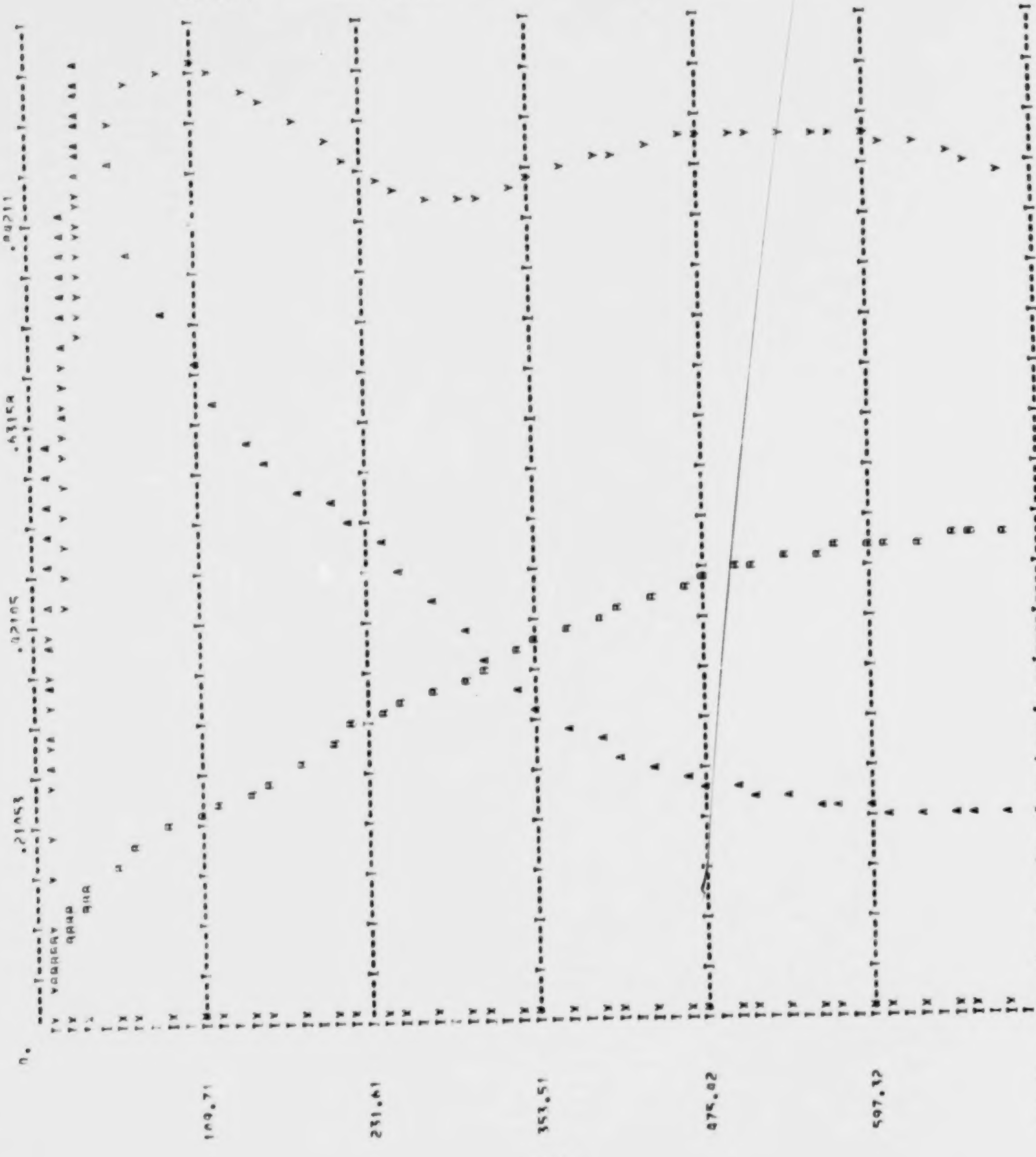
RUN D-S-19

```
INDEPENDENT VARIABLE IS  TIME   OVER RANGE     0.          34.760

                     DEPENDENT VARIABLES

SYMBOL              Y            R              X            Z
MAX PLOTTED      57.636        18.544         0.           0.
MIN PLOTTED      0.            0.             0.           0.
REMARKS         VERT. DIST.    RADIUS        HOR. DIST.   HOR. DIST.
```



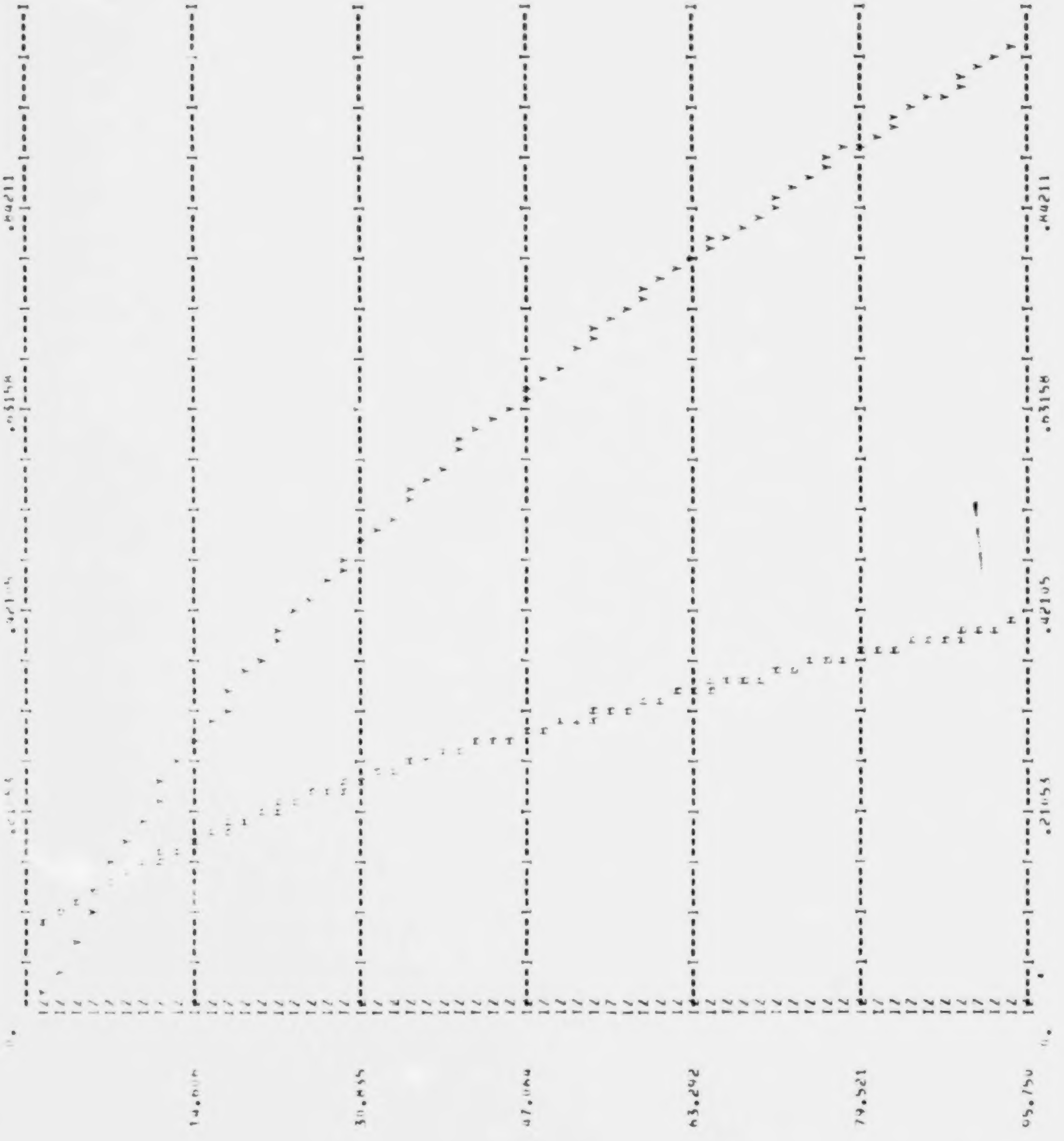
RUN D-S-19

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          719.22

                        DEPENDENT VARIABLES

SYMBOL                A                B              X                Y
MAX PLOTTED        9.2722          65.341          0.              66.043
MIN PLOTTED        0.              0.              0.              0.
REMARKS            VERT. SIZE.     HOR. SIZE       HOR. DIST.;     VERT. DIST.
```



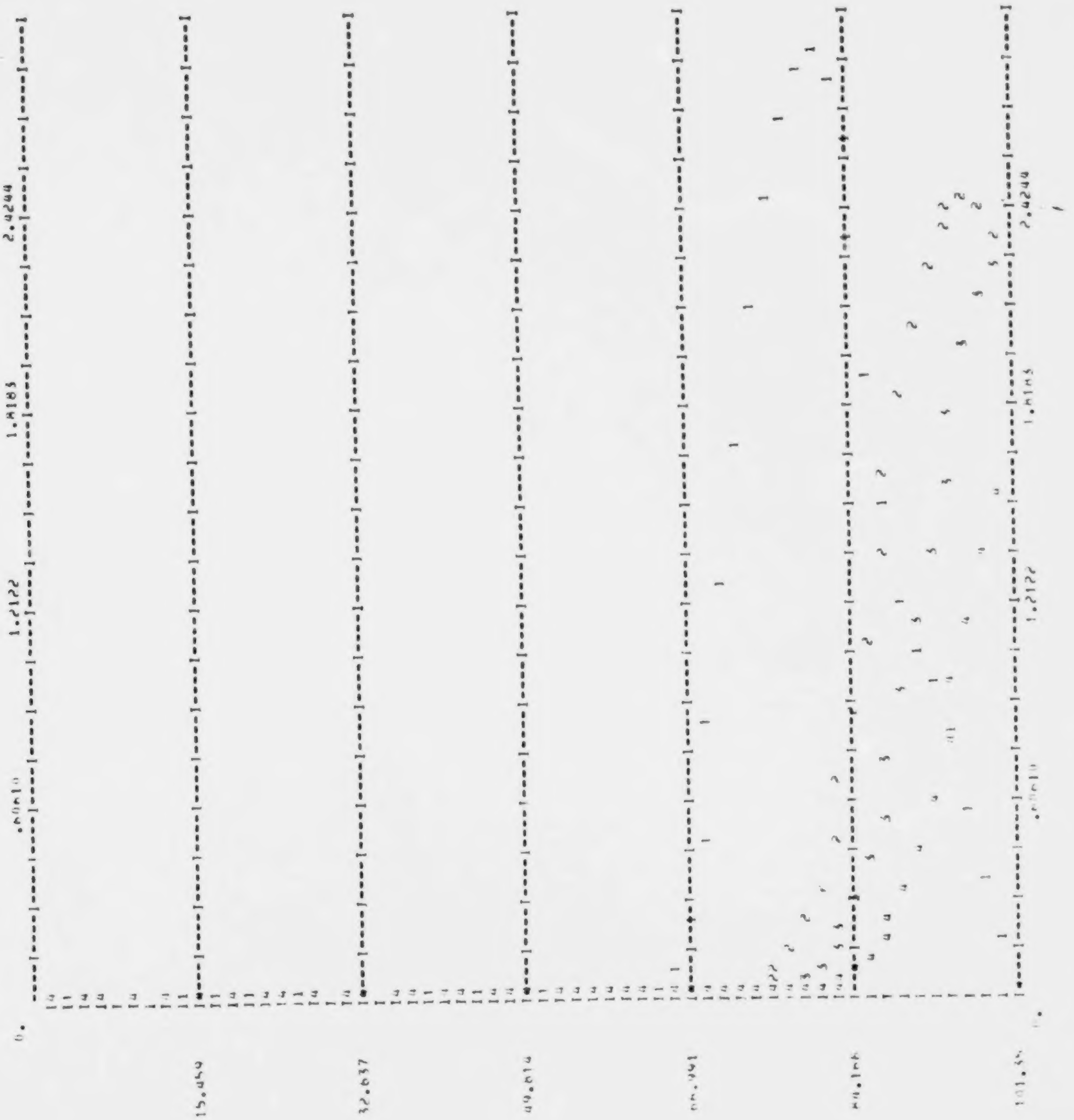
RUN D-LL-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          95.750

                    DEPENDENT VARIABLES

SYMBOL           Y              R              X              Z
MAX PLOTTED    75.280        22.669         0.             0.
MIN PLOTTED    0.            0.             0.             0.
REMARKS        VERT. DIST.    RADIUS        HOR. DIST.    HOR. DIST.
```



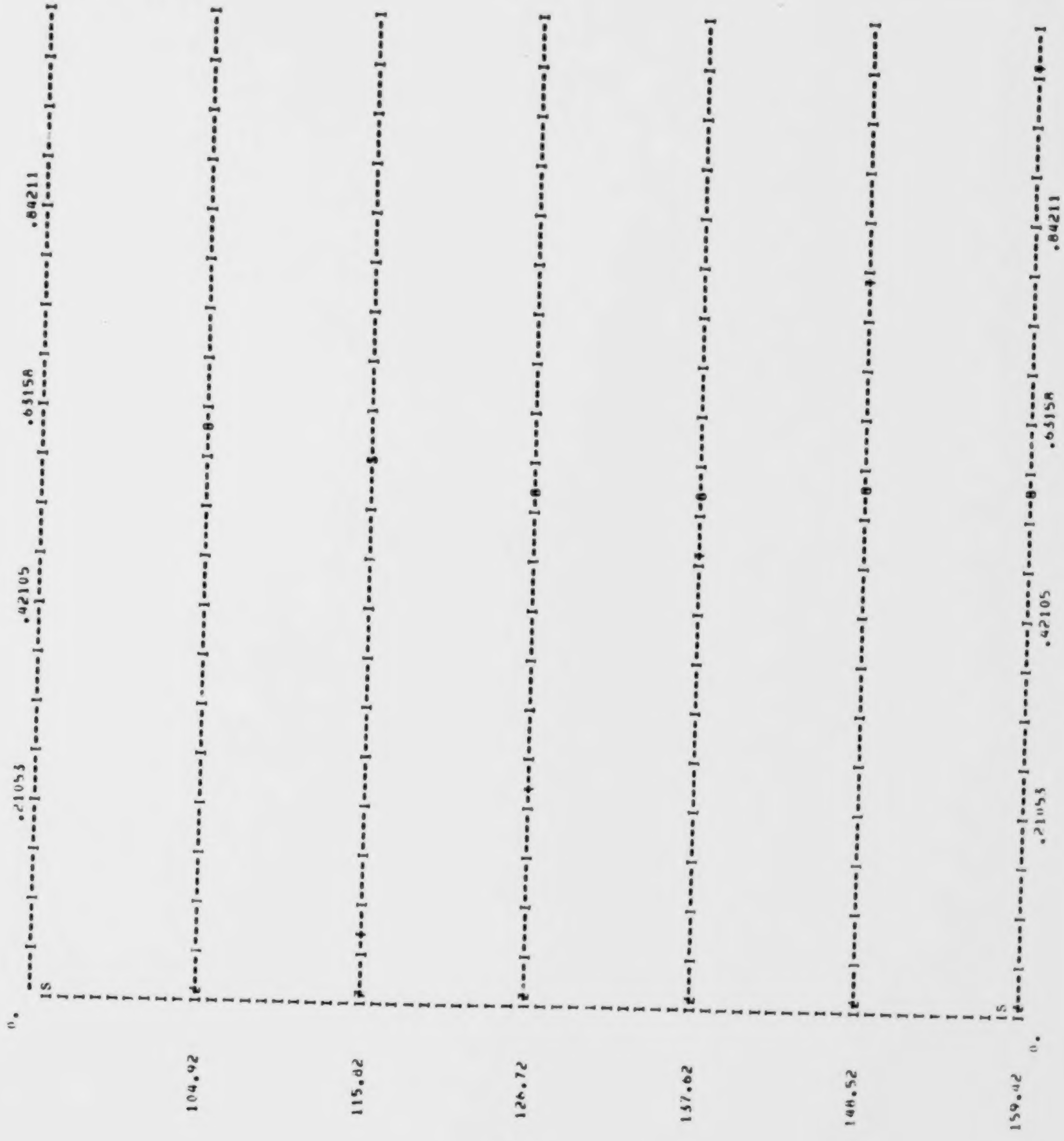
RUN D-LL-1

```
                              GRAPH OF   CDO   VS Y AT TIMES
   105.40650              138.00408              148.70995              159.41581

         RANGE OF    Y    PLOTTED        0.                       101.34528
         RANGE OF   CDO   PLOTTED        0.                       2.8789937
```



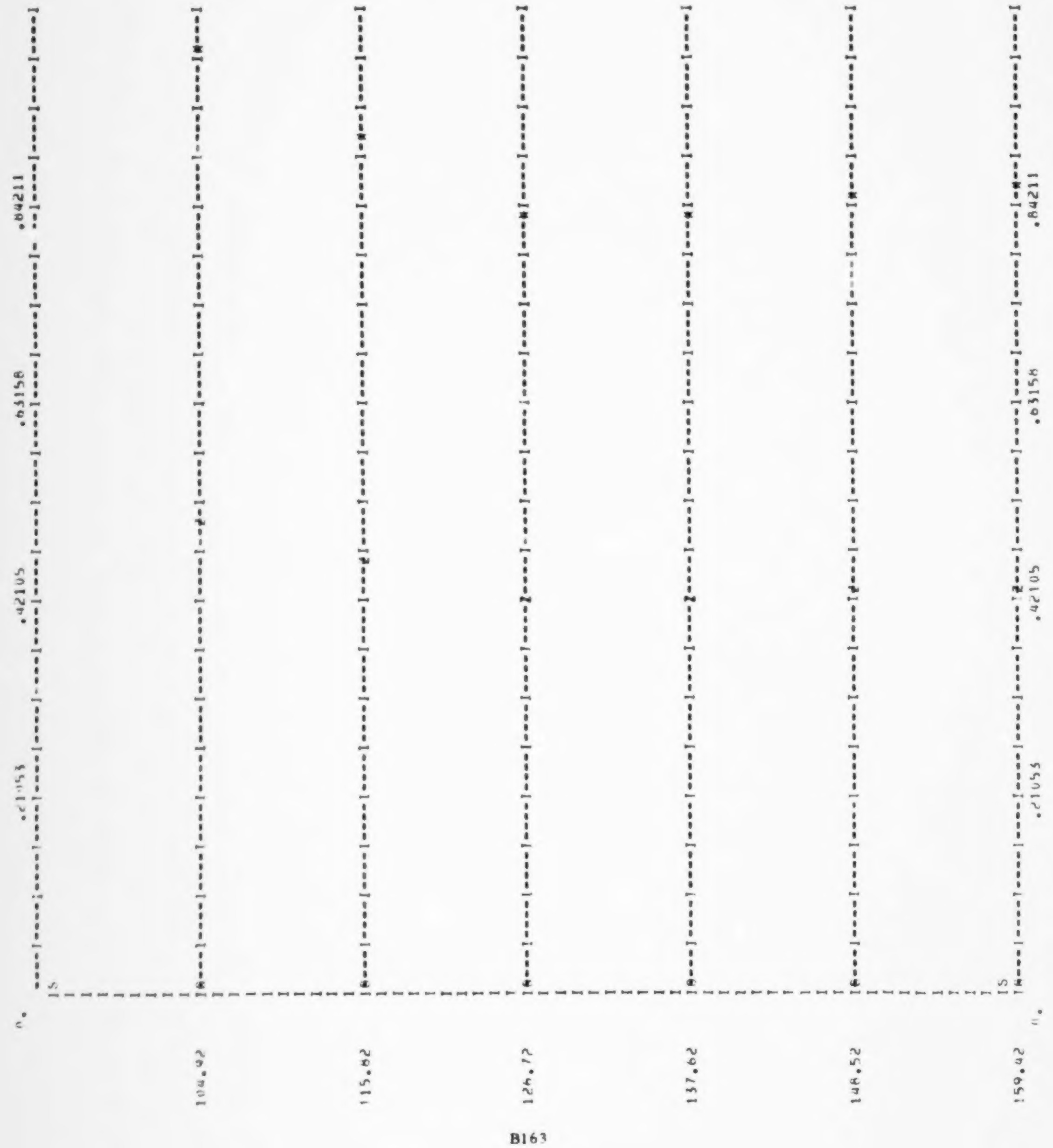
RUN D-LL-1

```
PLOT OF TOT BURY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE            95.111712          159.41561
MAXIMUM T,X,Z,S       42.819217          0.                 0.                 22.483016
MINIMUM T,X,Z,S      0.                  0.                 0.                0.
```



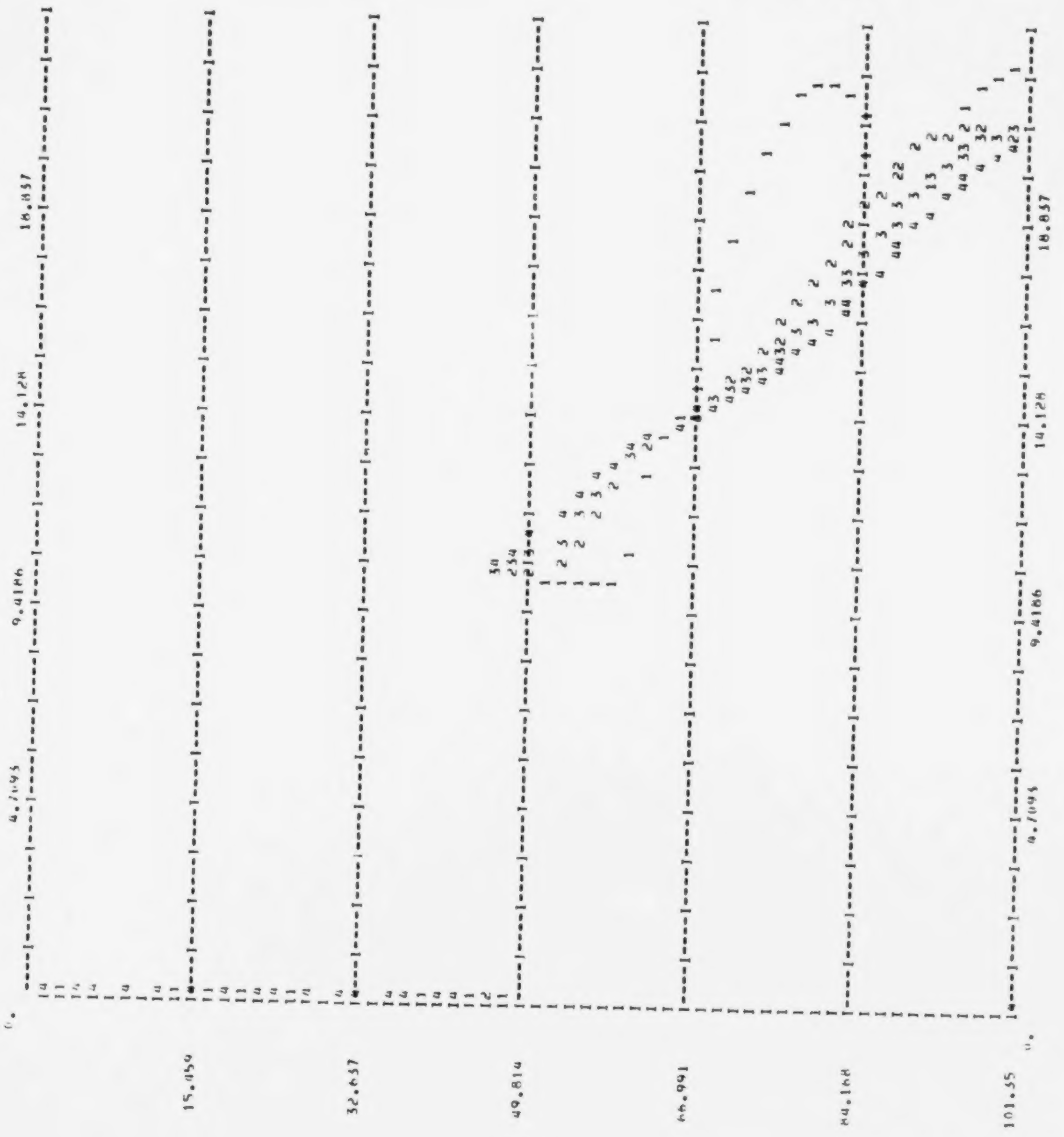
RUN D-LL-1

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

TIME RANGE=          95.111712          159.41581
MAXIMUM X,Z,S        126.37150          126.37150          0.
MINIMUM X,Z,S       0.                 0.                  0.
```



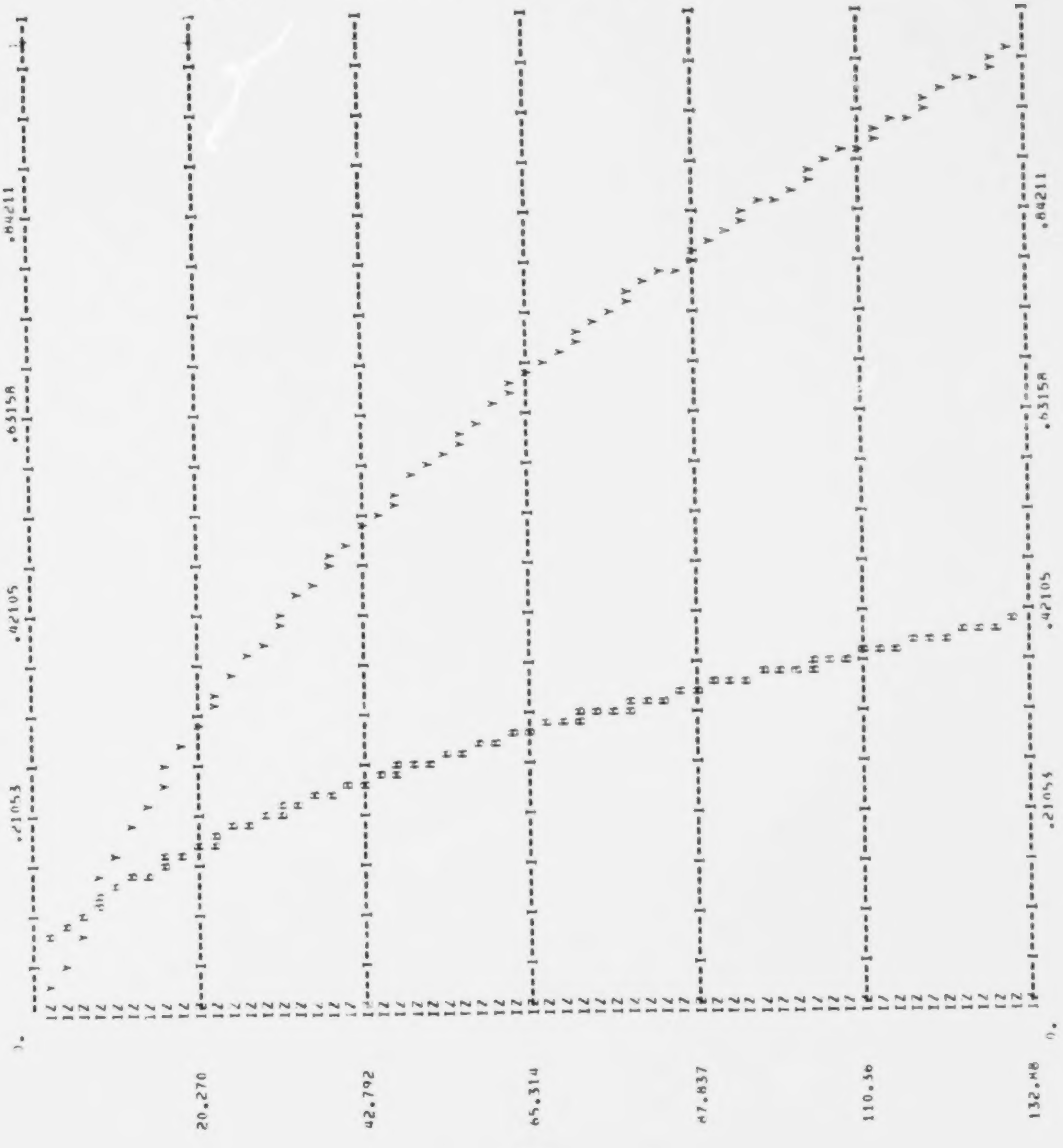
RUN D-LL-1

```
                          GRAPH OF   SIZE  VS Y AT TIMES
105.40650             138.00409             148.70995             159.41581

          RANGE OF     Y   PLOTTED        0.                   101.34528
          RANGE OF   SIZE  PLOTTED        0.                   22.369154
```



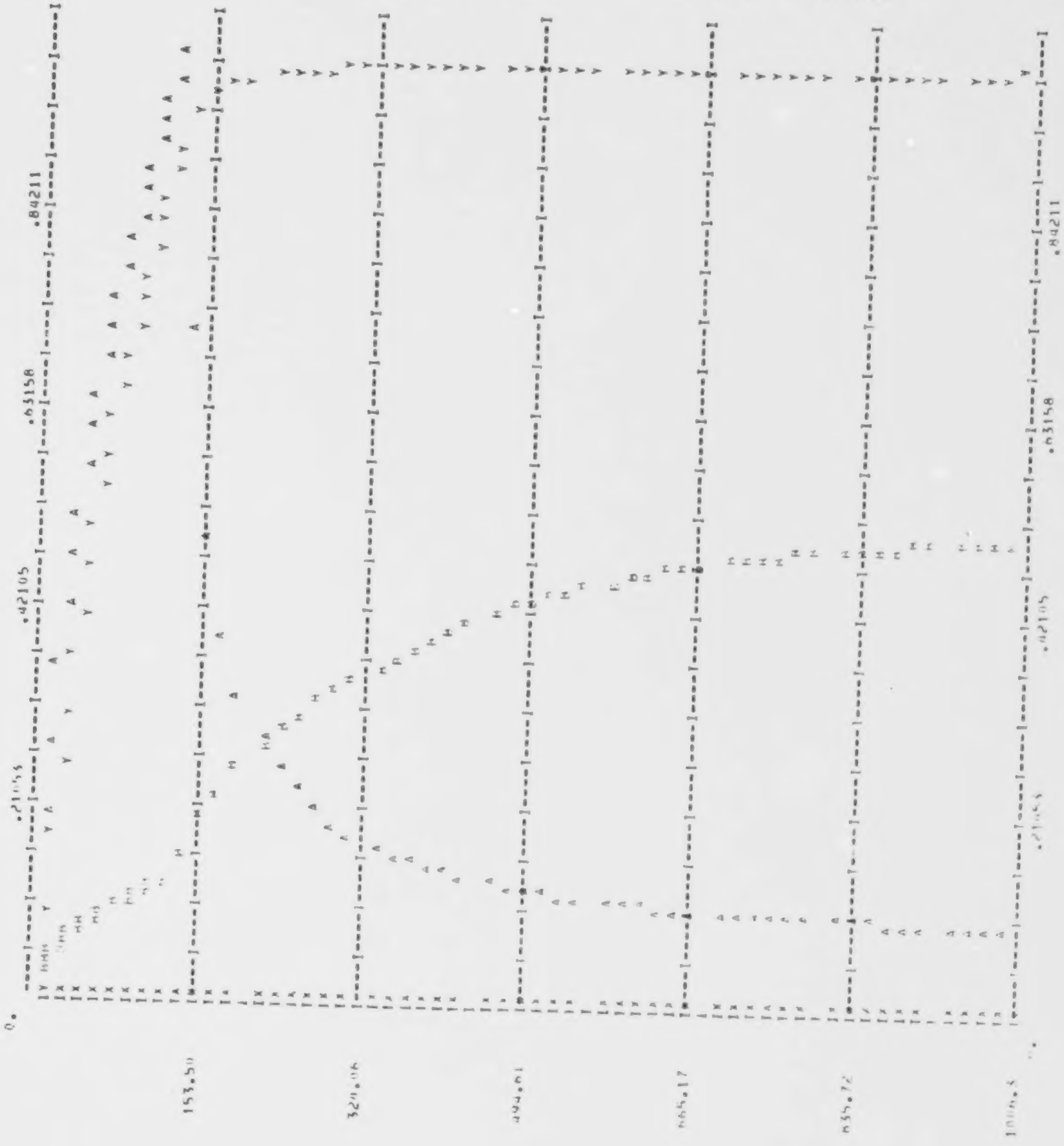
RUN D-F-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          132.88

                        DEPENDENT VARIABLES

SYMBOL              Y             H              X            Z
MAX PLOTTED     90.475        26.261          0.           0.
MIN PLOTTED     0.            0.              0.           0.
REMARKS         VERT. DIST.    RADIUS        HOR. DIST.    HOR. DIST.
```



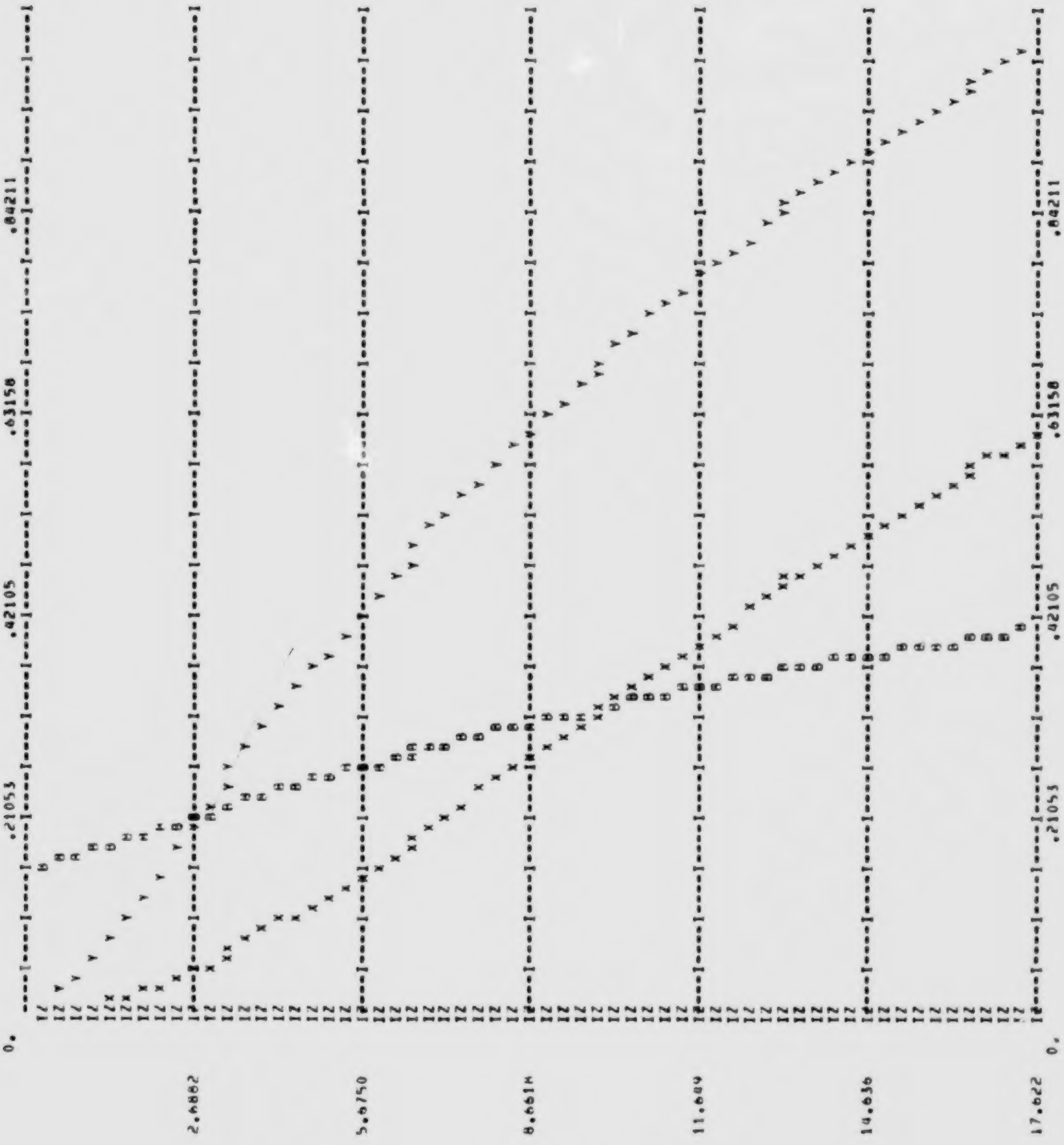
RUN D-F-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          1006.5

                        DEPENDENT VARIABLES

SYMBOL                A                H                X               Y
MAX PLOTTED      13.907          104.95          0.              99.419
MIN PLOTTED      0.              0.              0.              0.
REMARKS          VERT. SIZE.     HOR. SIZE       HOR. DIST.      VERT. DIST.
```



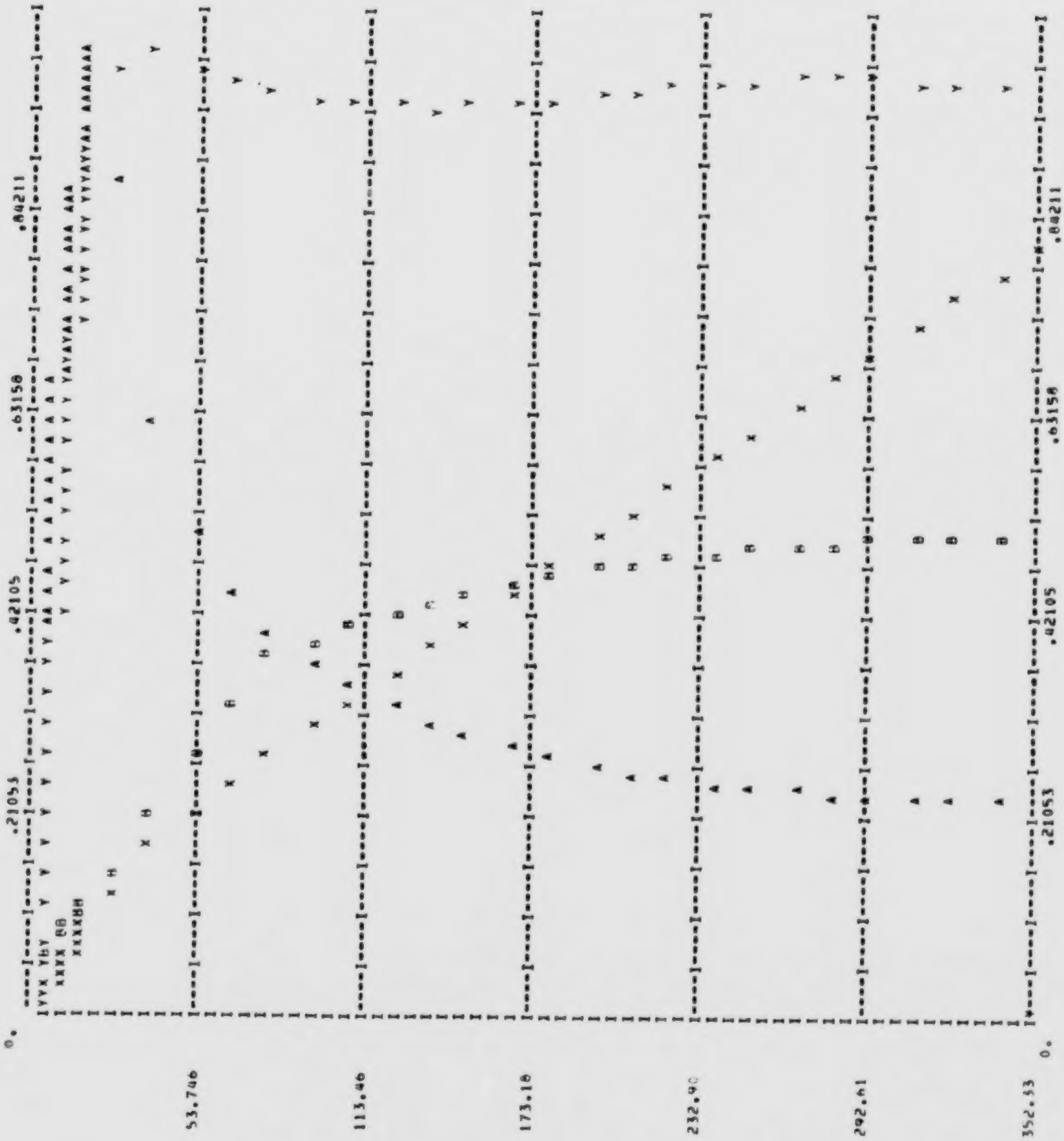
RUN D-FS-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          17.622

                        DEPENDENT VARIABLES

SYMBOL               Y            B             X             Z
MAX PLOTTED     33.385       12.980        13.380        0.
MIN PLOTTED     0.           0.            0.            0.
REMARKS         VERT. DIST.   RADIUS       HOR. DIST.    HOR. DIST.
```



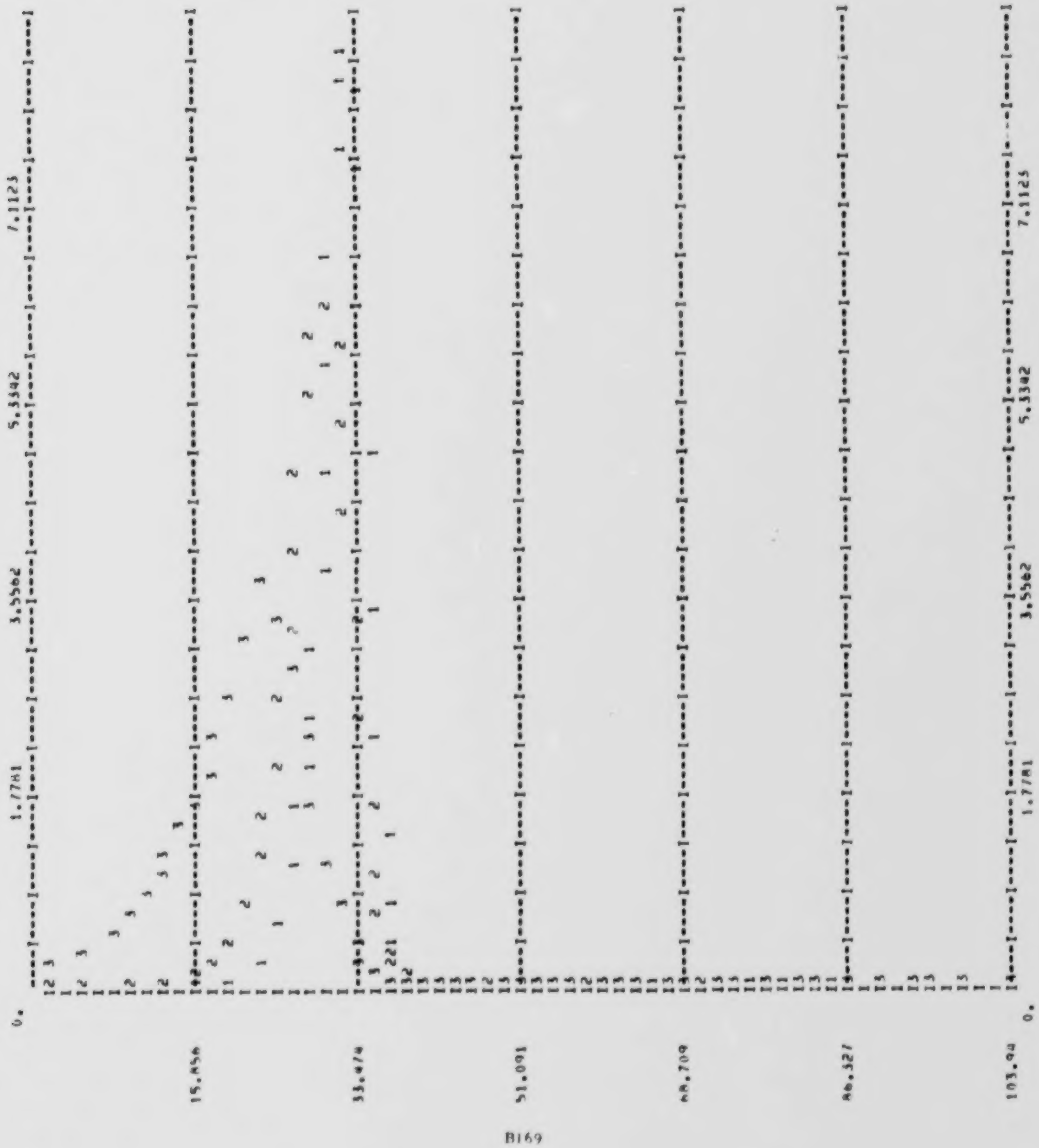
RUN D-FS-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          352.33

                    DEPENDENT VARIABLES

SYMBOL              A            B            X            Y
MAX PLOTTED      6.4658       58.914       122.55       36.886
MIN PLOTTED      0.           0.           0.           0.
REMARKS          VERT. SIZE.  HOR. SIZE    HOR. DIST.   VERT. DIST.
```



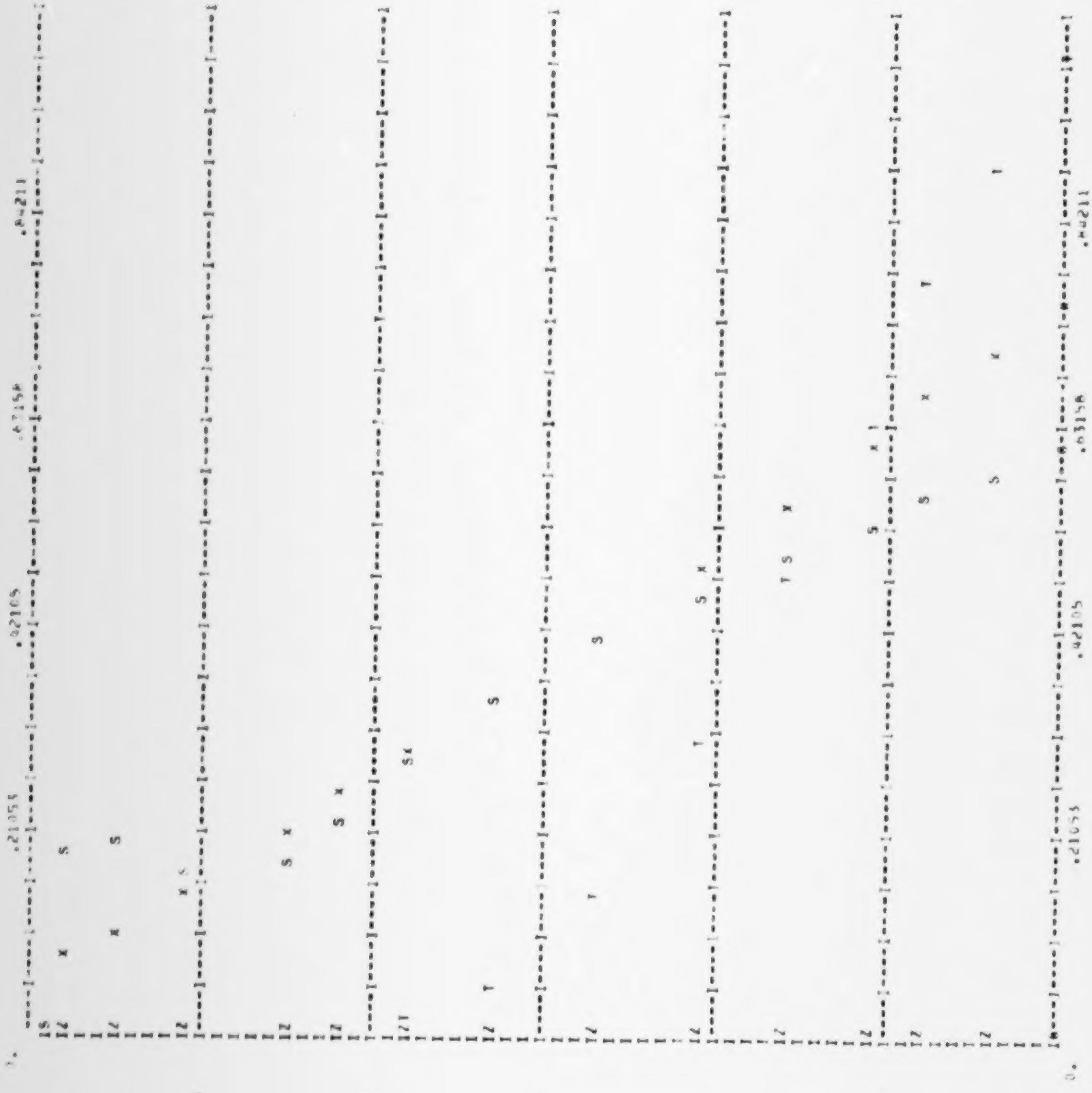
RUN D-FS-1

```
                                GRAPH OF   COD   VS Y AT TIMES
530.04855                  771.18493              1503.8372           -1.0000000

        RANGE OF    Y    PLOTTED        0.                         103.94460
        RANGE OF   COD   PLOTTED        0.                         8.8458893
```



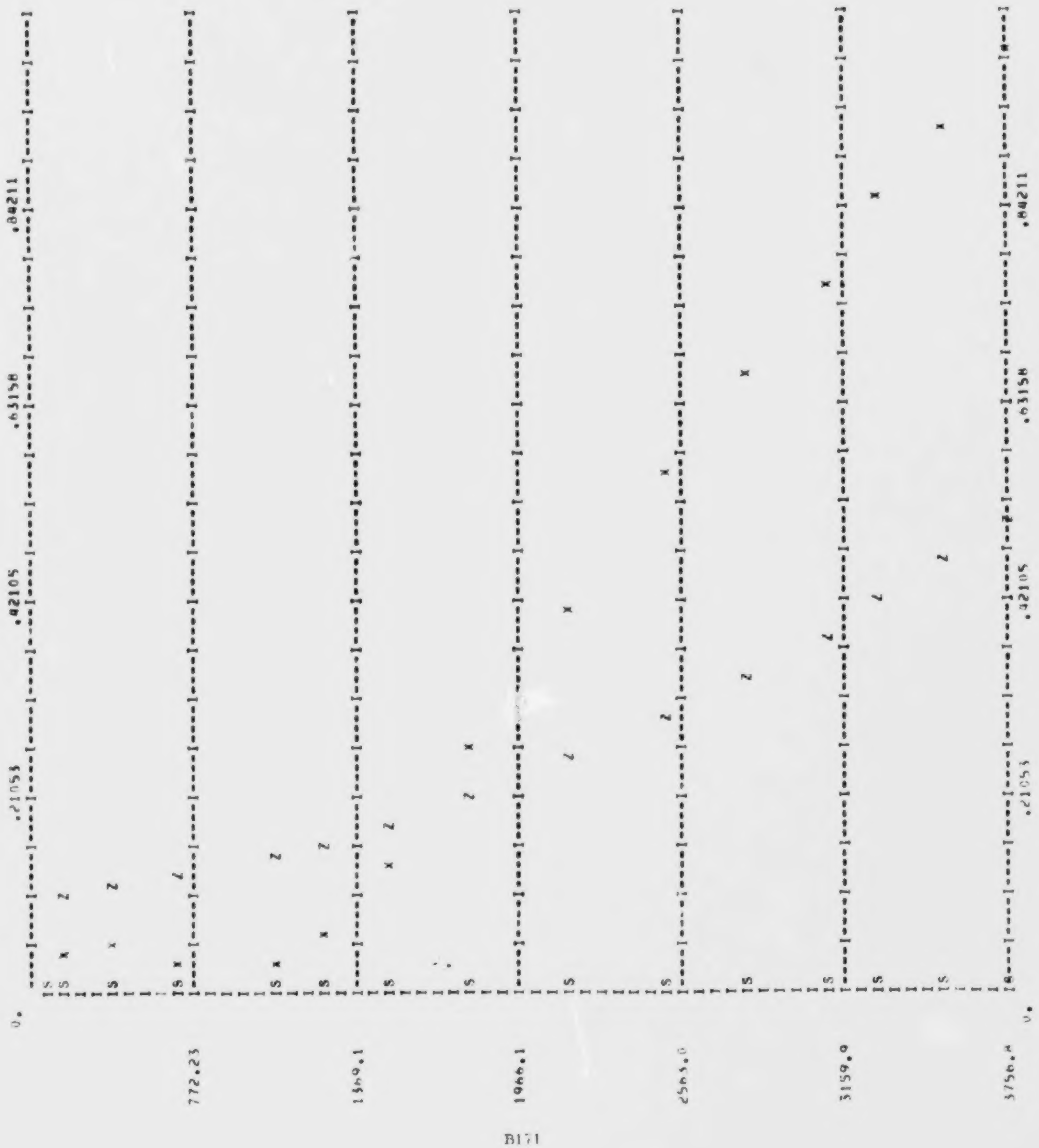
RUN D-FS-1

```
PLOT OF TOT BDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE            235.00873          3756.7877
MAXIMUM T,X,Z,S       28.973338          3050.2918         0.                 234.94490
MINIMUM T,X,Z,S      0.                 0.                 0.                0.
```



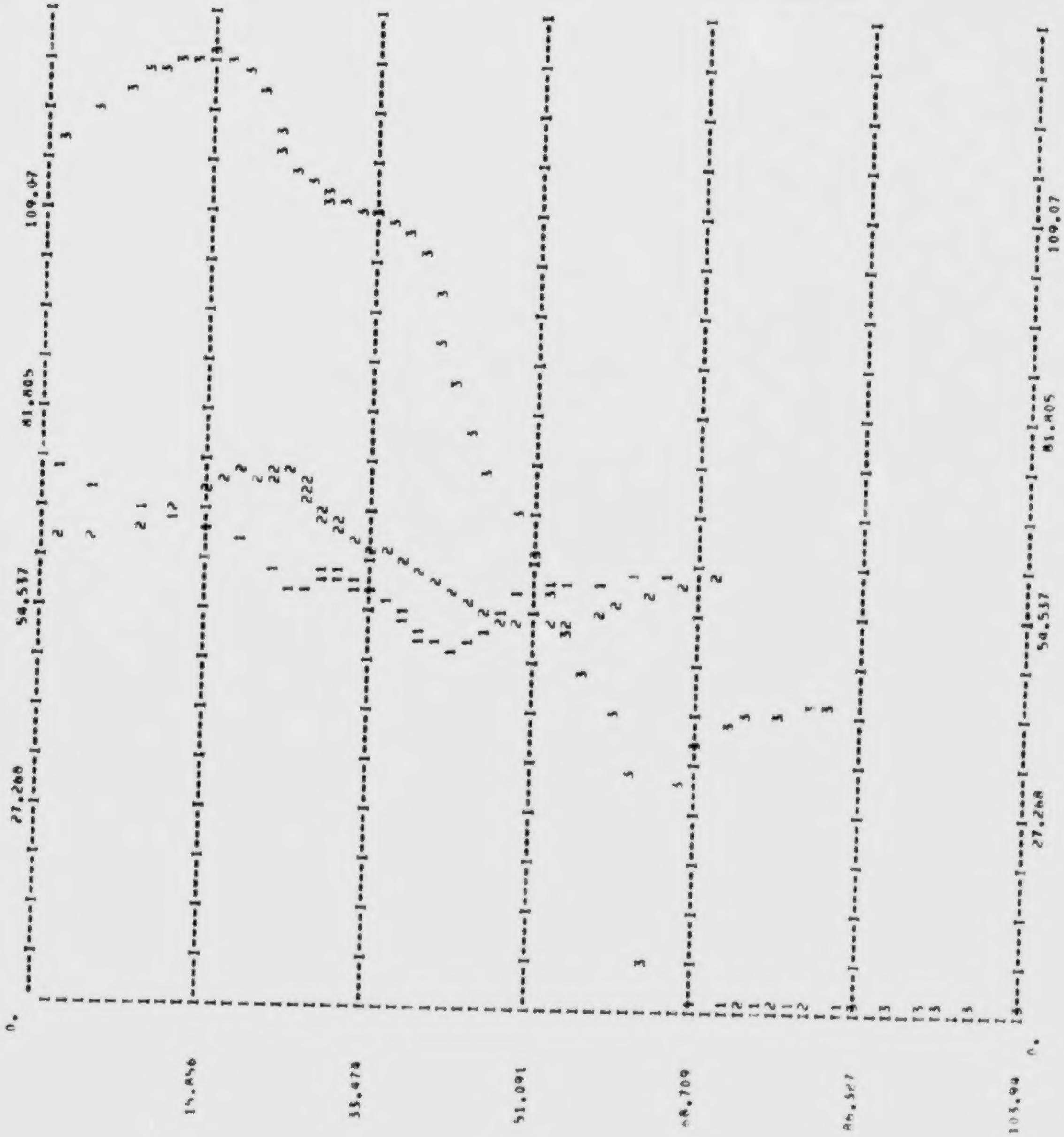
RUN D-FS-1

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

TIME RANGE=               235.00873            3756.7877
MAXIMUM X,Z,S             62914.068            3026.8881           0.
MINIMUM X,Z,S           0.                    0.                   0.
```



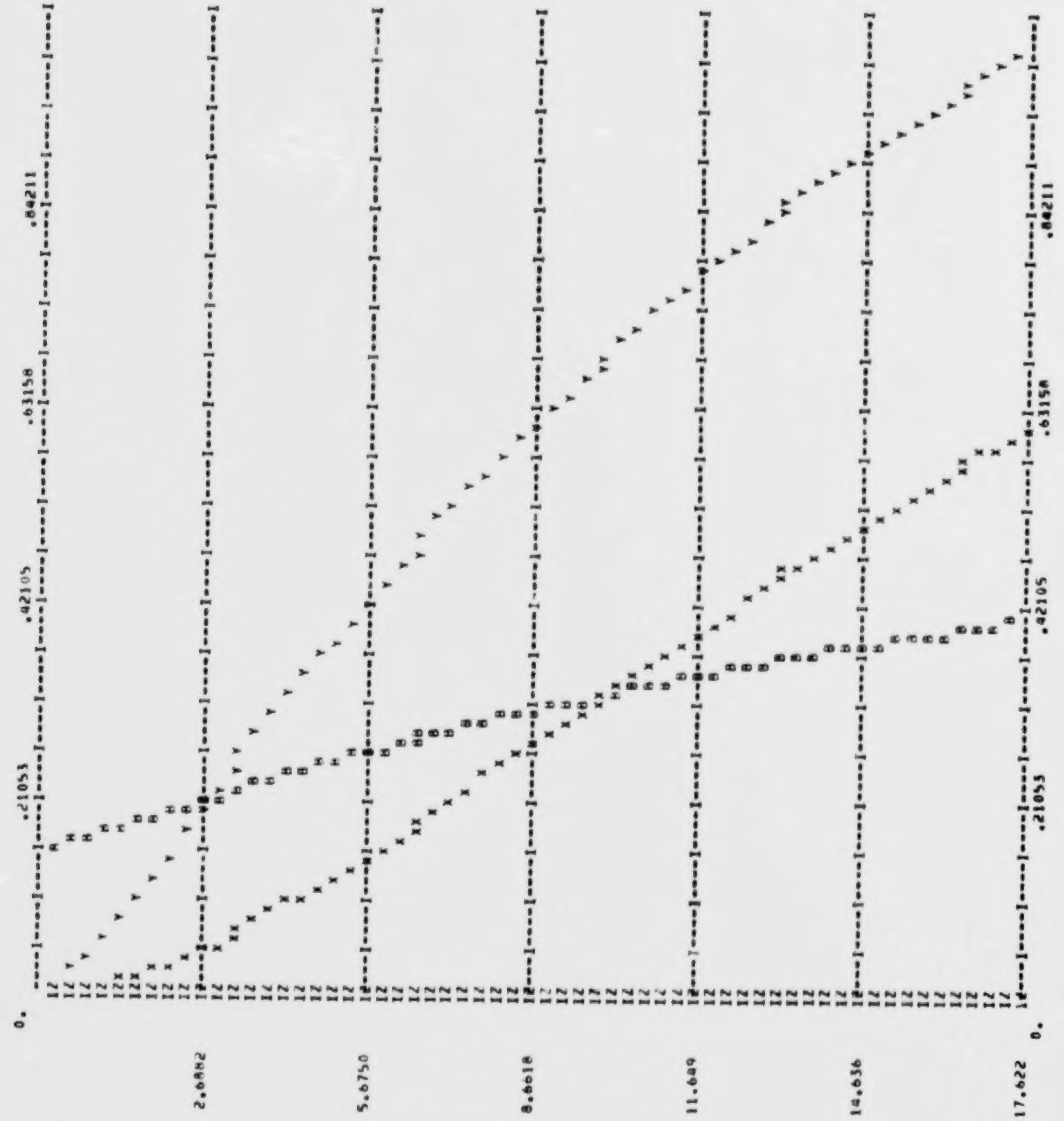
RUN D-FS-1

```
                                GRAPH OF    SIZE  VS Y AT TIMES
          530.04855           771.18493            1503.8372            -1.0000000

                    RANGE OF    Y    PLOTTED        0.                   103.94460
                    RANGE OF  SIZE   PLOTTED        0.                   129.52452
```



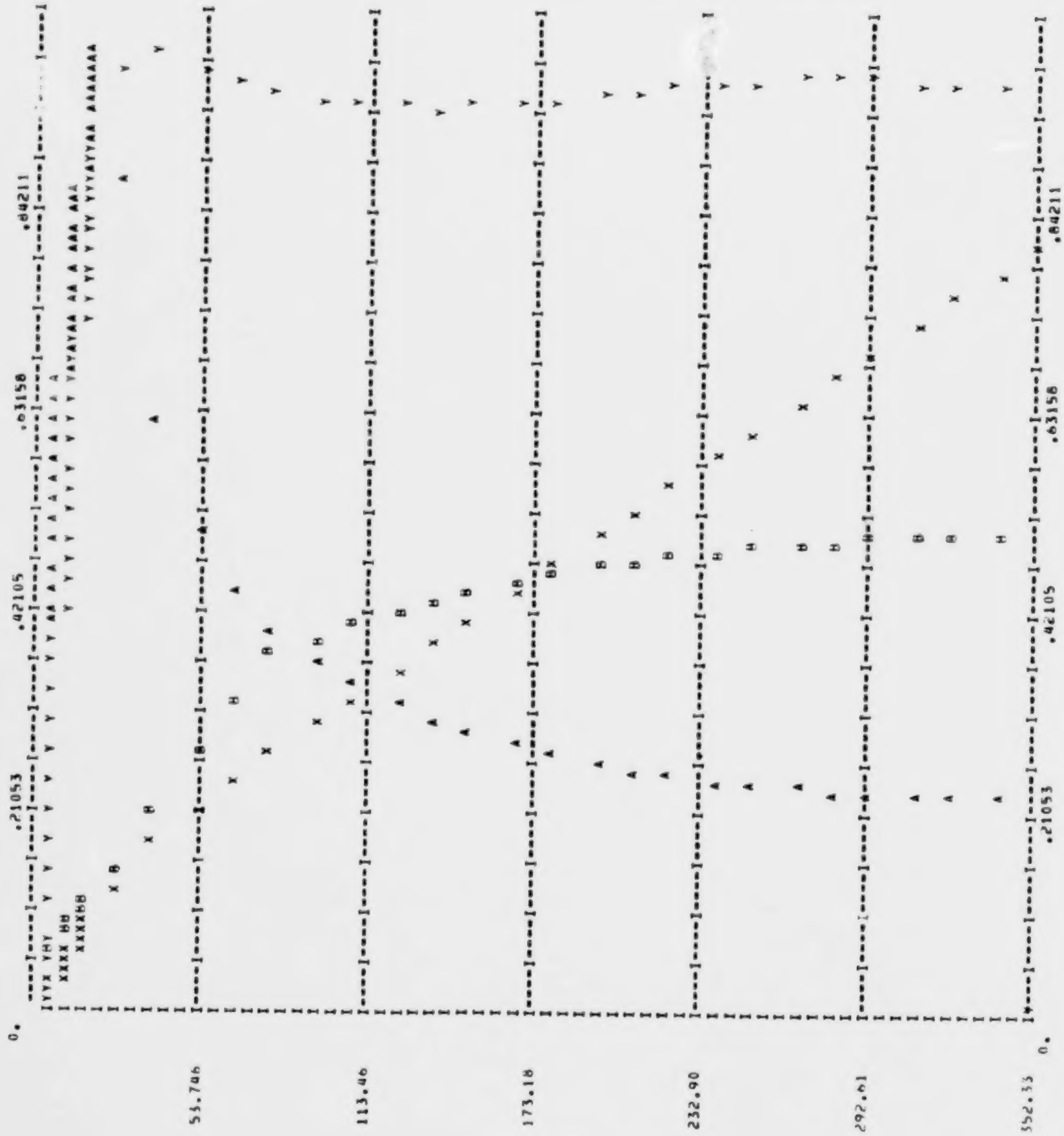
RUN D-FS-2

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          17.622

                         DEPENDENT VARIABLES

SYMBOL              Y             R             X             Z
MAX PLOTTED     33.385        12.980        13.380        0.
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. DIST.    RADIUS       HOR. DIST.    HOR. DIST.
```



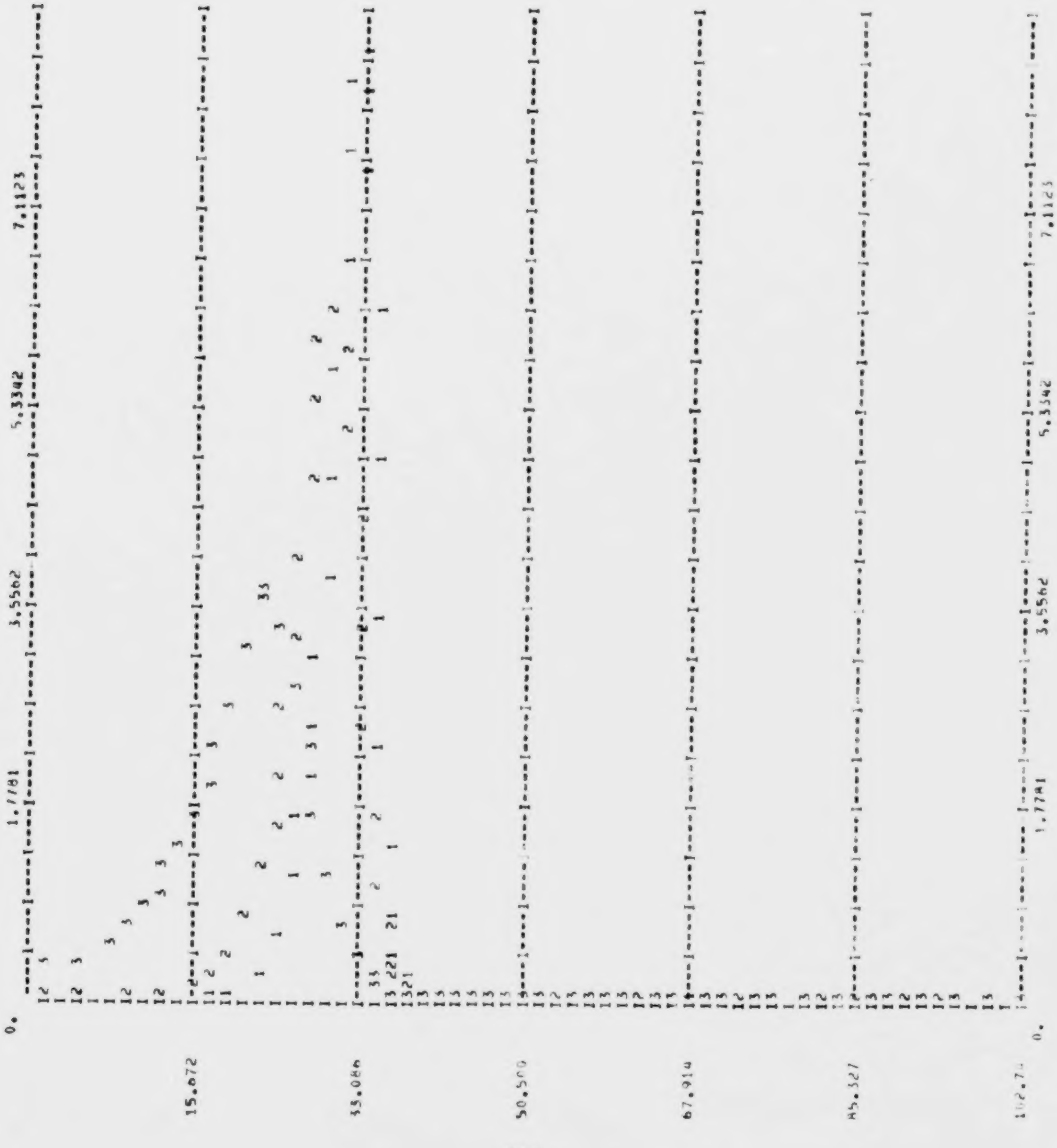
RUN D-FS-2

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE      0.          352.33

                         DEPENDENT VARIABLES

SYMBOL                  A                B                X                Y
MAX PLOTTED        6.4658           58.914           122.55           36.886
MIN PLOTTED       0.               0.               0.               0.
REMARKS           VERT. SIZE.      HOR. SIZE        HOR. DIST.       VERT. DIST.
```



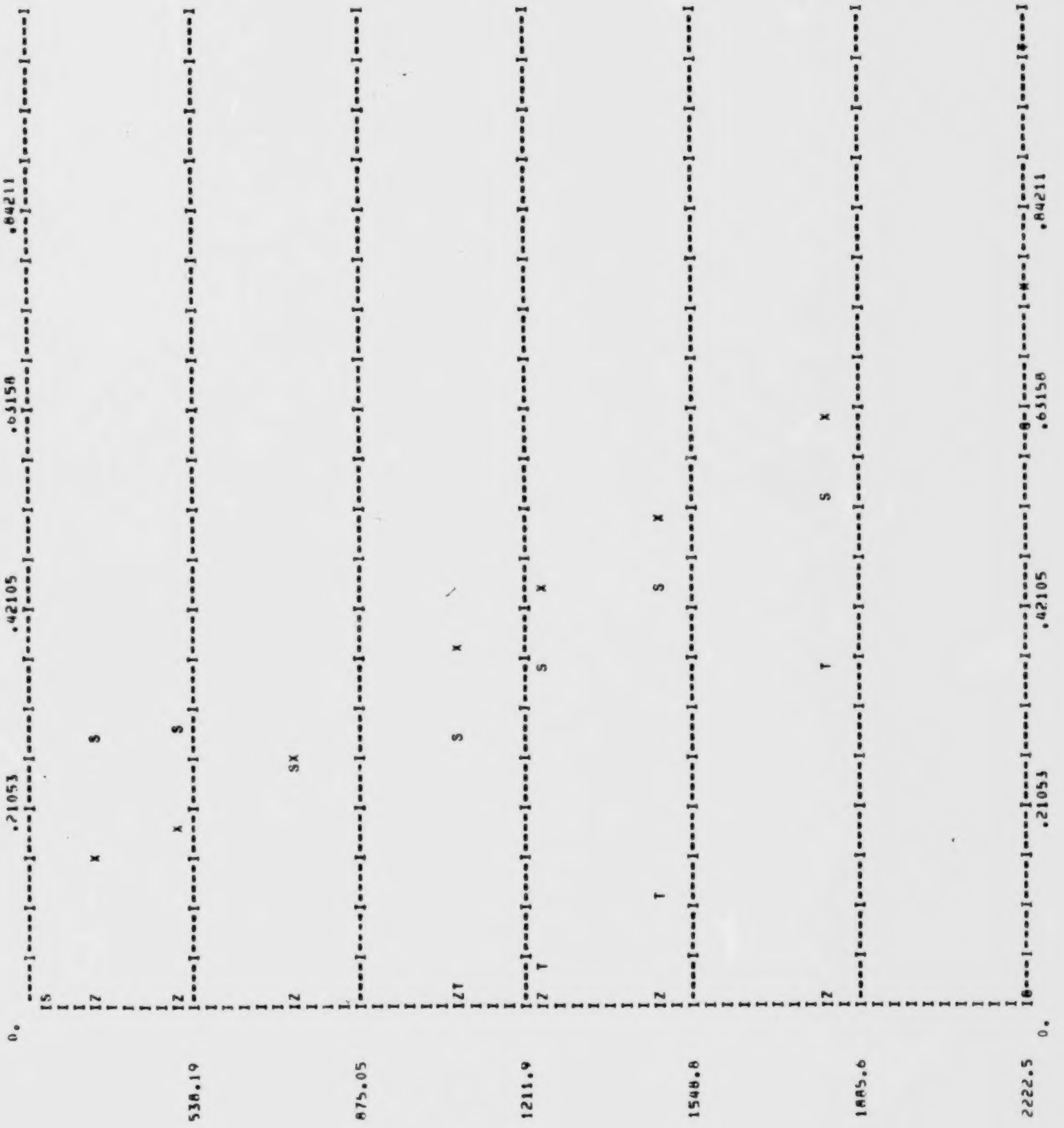
RUN D-FS-2

```
                        GRAPH OF    COD   VS Y AT TIMES
530.04656             771.19000          1513.0445            -1.0000000

      RANGE OF    Y   PLOTTED        0.                     102.74115
      RANGE OF   COD  PLOTTED        0.                     8.8903867
```



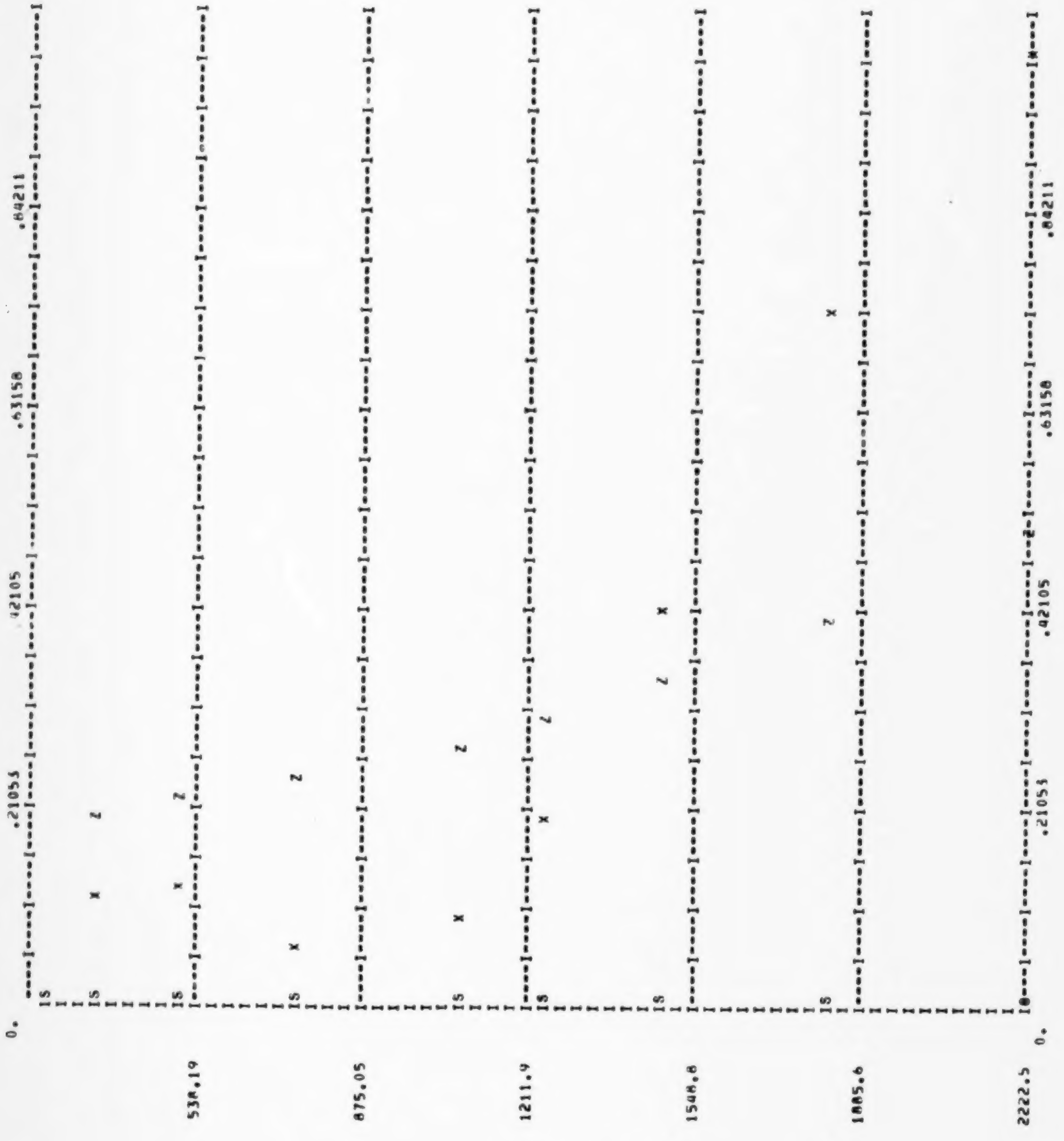
RUN D-FS-2

```
PLOT OF TOT BDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE             235.00873          2222.5126
MAXIMUM T,X,Z,S        1.1427988          1696.8249          0.                  155.05518
MINIMUM T,X,Z,S       0.                 0.                  0.                 0.
```



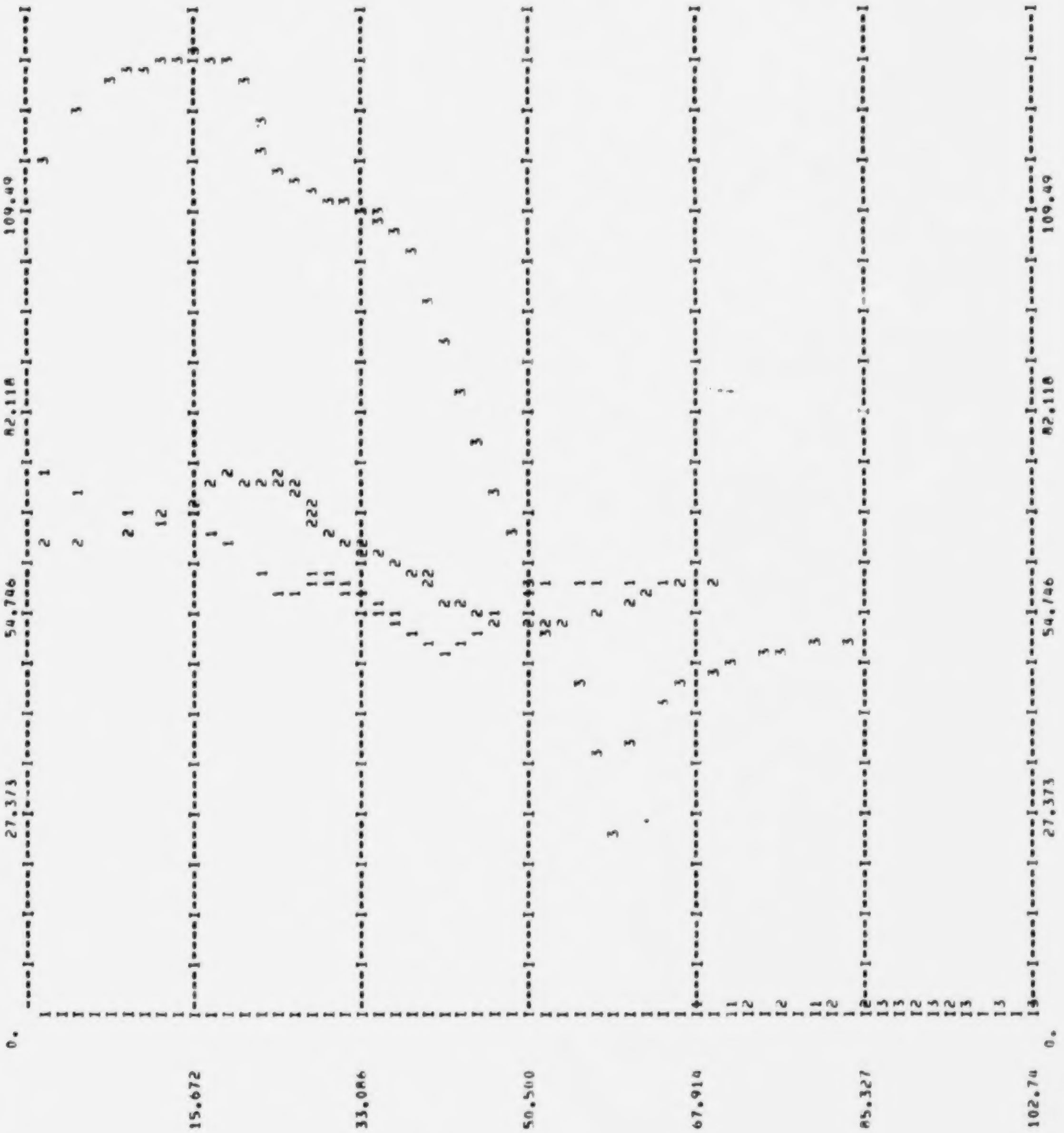
RUN D-FS-2

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

TIME RANGE=          235.00873          2222.5126
MAXIMUM X,Z,S        23018.100           1569.4798          0.
MINIMUM X,Z,S       0.                 0.                   0.
```



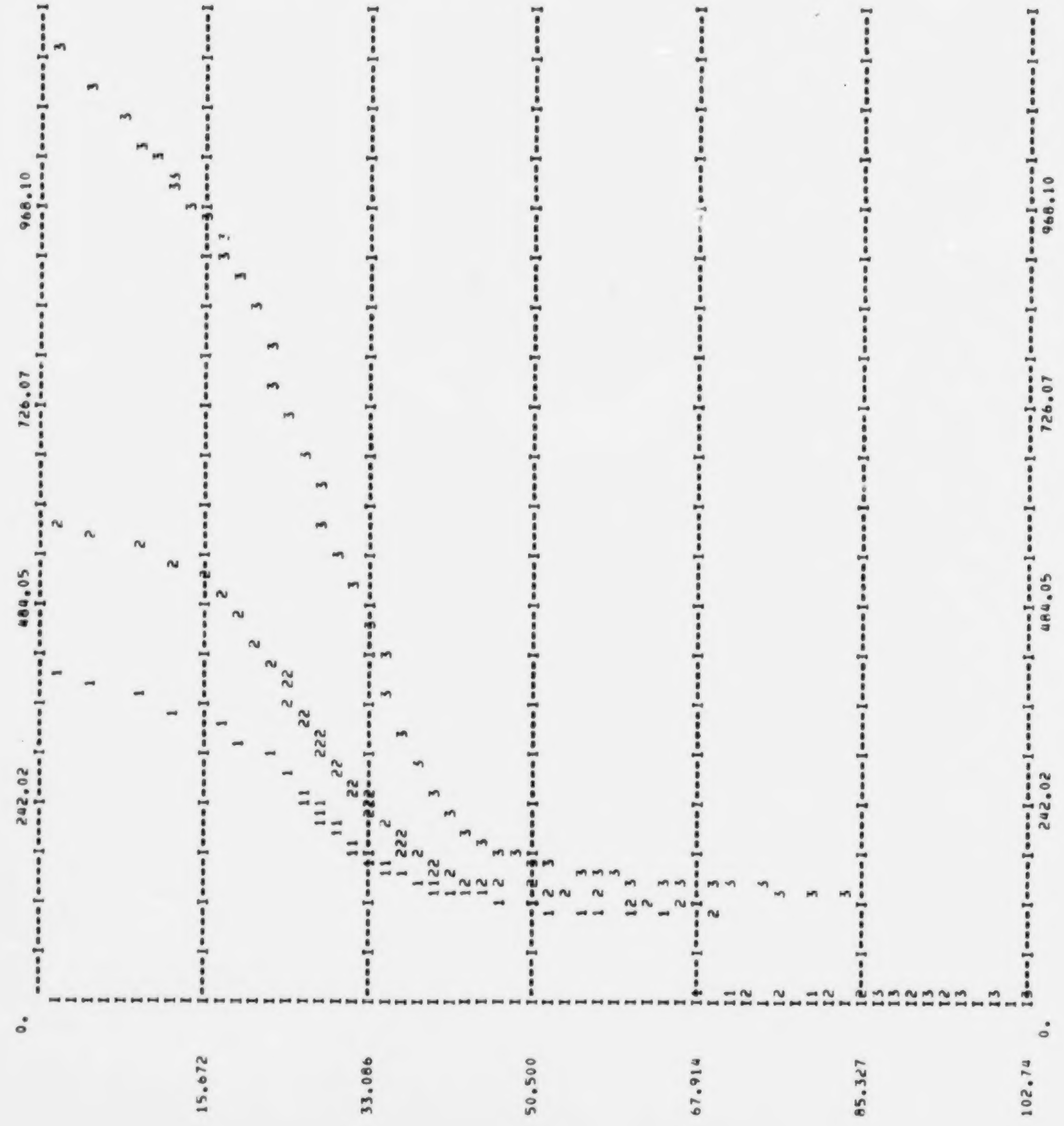
RUN D-FS-2

```
                          GRAPH OF   SIZE  VS Y AT TIMES
530.04856          771.19000          1513.0445          -1.0000000

          RANGE OF         PLOTTED        0.                 102.74115
          RANGE OF   SIZE  PLOTTED        0.                 130.02087
```



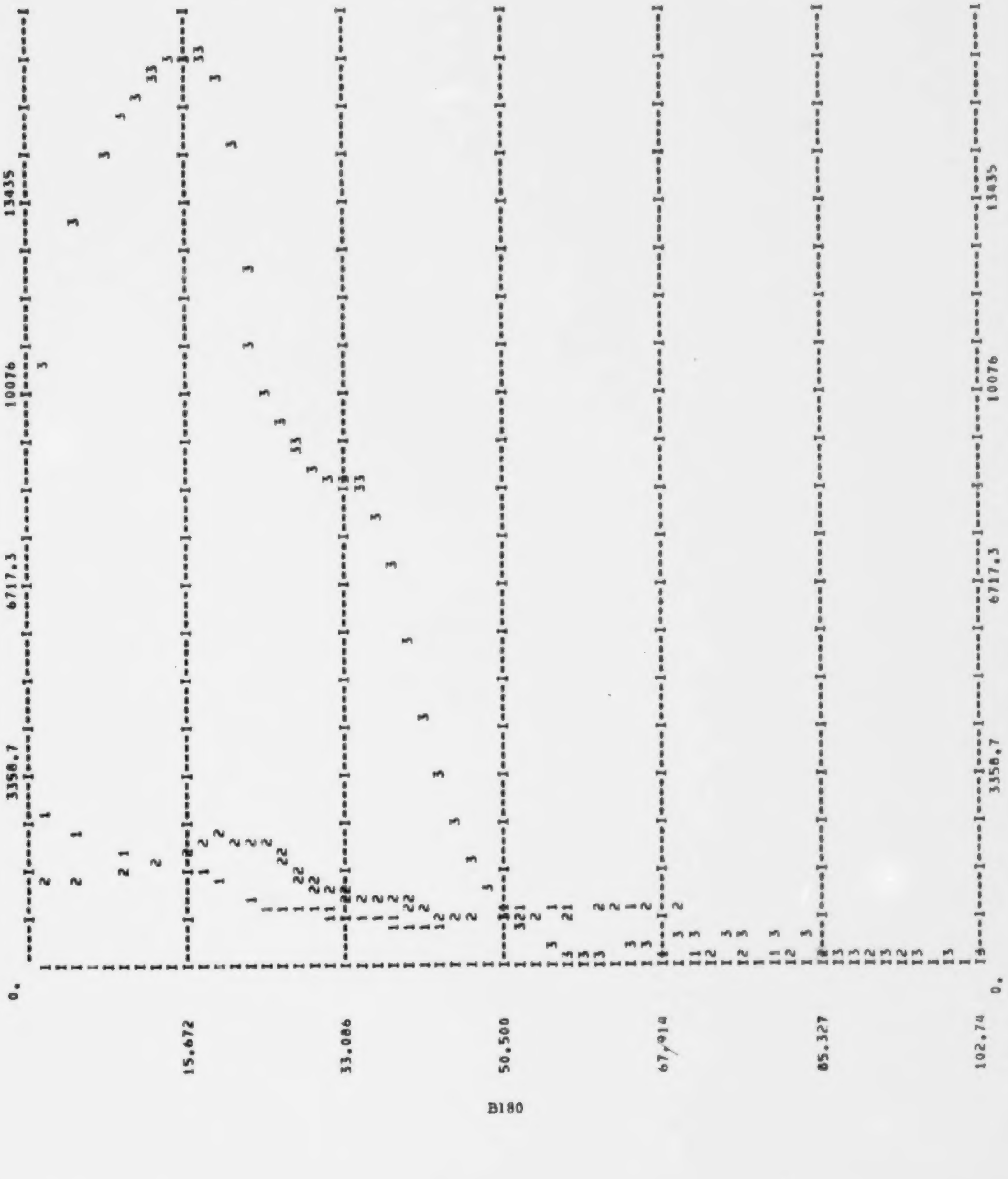
RUN D-FS-2

```
                               GRAPH OF     XO    VS Y AT TIMES
530.04856             771.19000             1513.0445           -1.0000000

             RANGE OF     Y    PLOTTED        0.                 102.74115
             RANGE OF     XO   PLOTTED        0.                 1149.6136
```



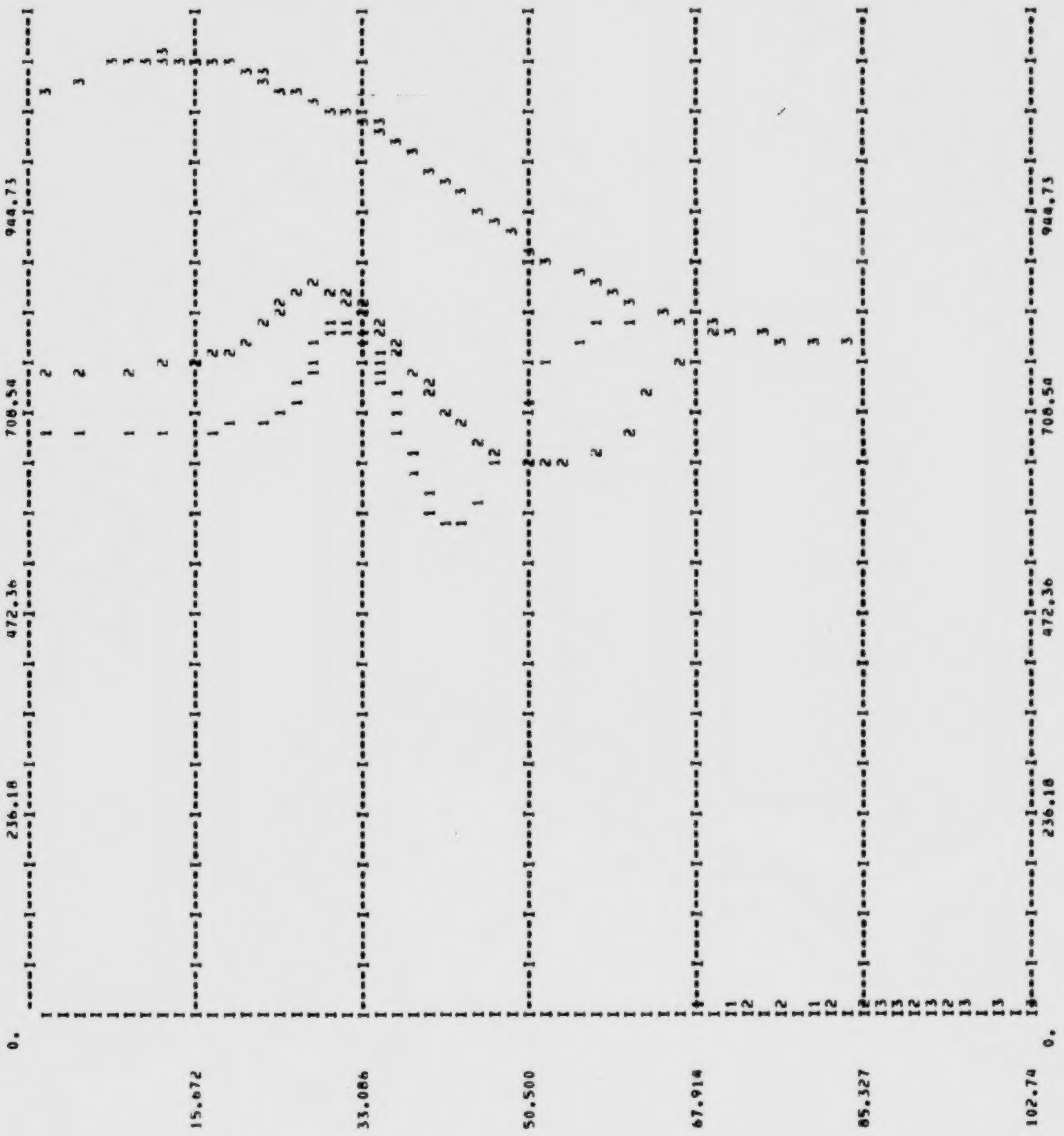
RUN D-FS-2

```
                         GRAPH OF SIGMA-X VS Y AT TIMES
530.04856            771.19000            1513.0445            -1.0000000

          RANGE OF     Y    PLOTTED        0.                   102.74115
          RANGE OF SIGMA-X PLOTTED        0.                   15953.694
```

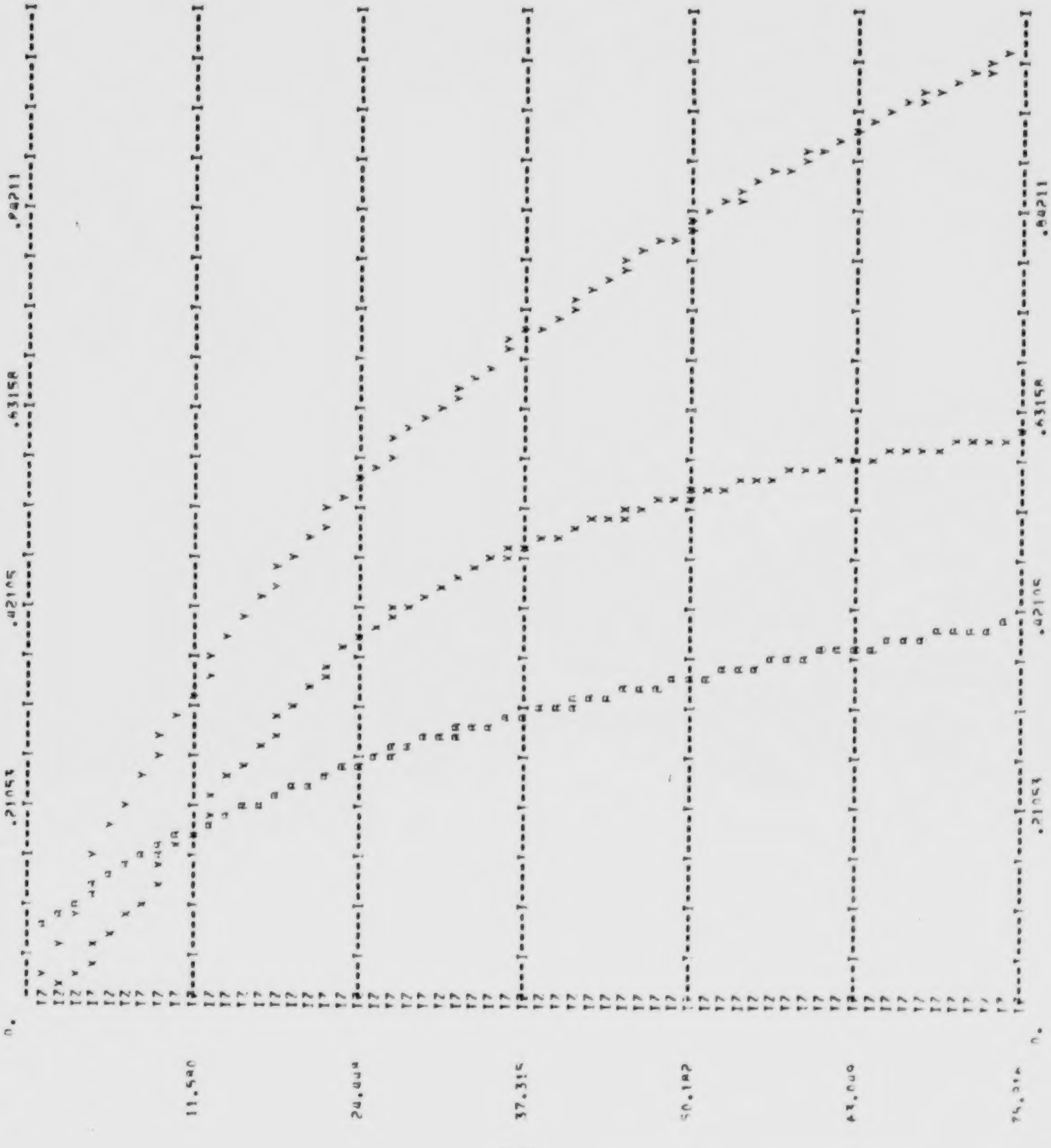


RUN D-FS-2

```
                              GRAPH OF SIGMA-Z VS Y AT TIMES
         530.04856          771.19000          1513.0445          -1.0000000
              RANGE OF     Y    PLOTTED       0.                 102.74115
              RANGE OF SIGMA-Z PLOTTED       0.                 1121.8625
```

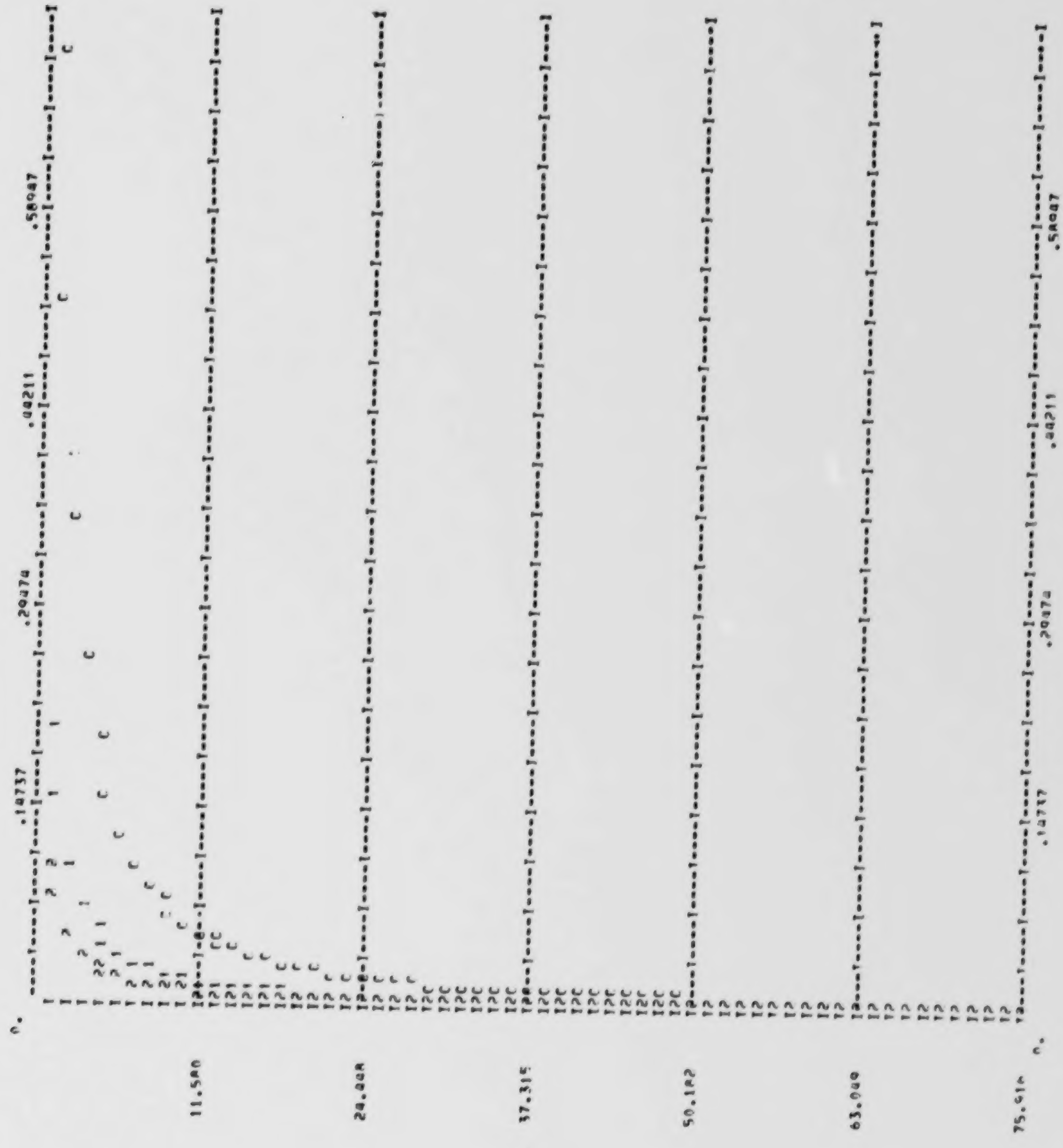


```
                         RUN D-2S-1
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.           75.916

                     DEPENDENT VARIABLES

SYMBOL              Y            R             X            Z
MAX PLOTTED      90.092       24.779        31.437        0.
MIN PLOTTED      0.           0.            0.            0.
REMARKS          VERT. DIST.   RADIUS       HOR. DIST.    HOR. DIST.
```



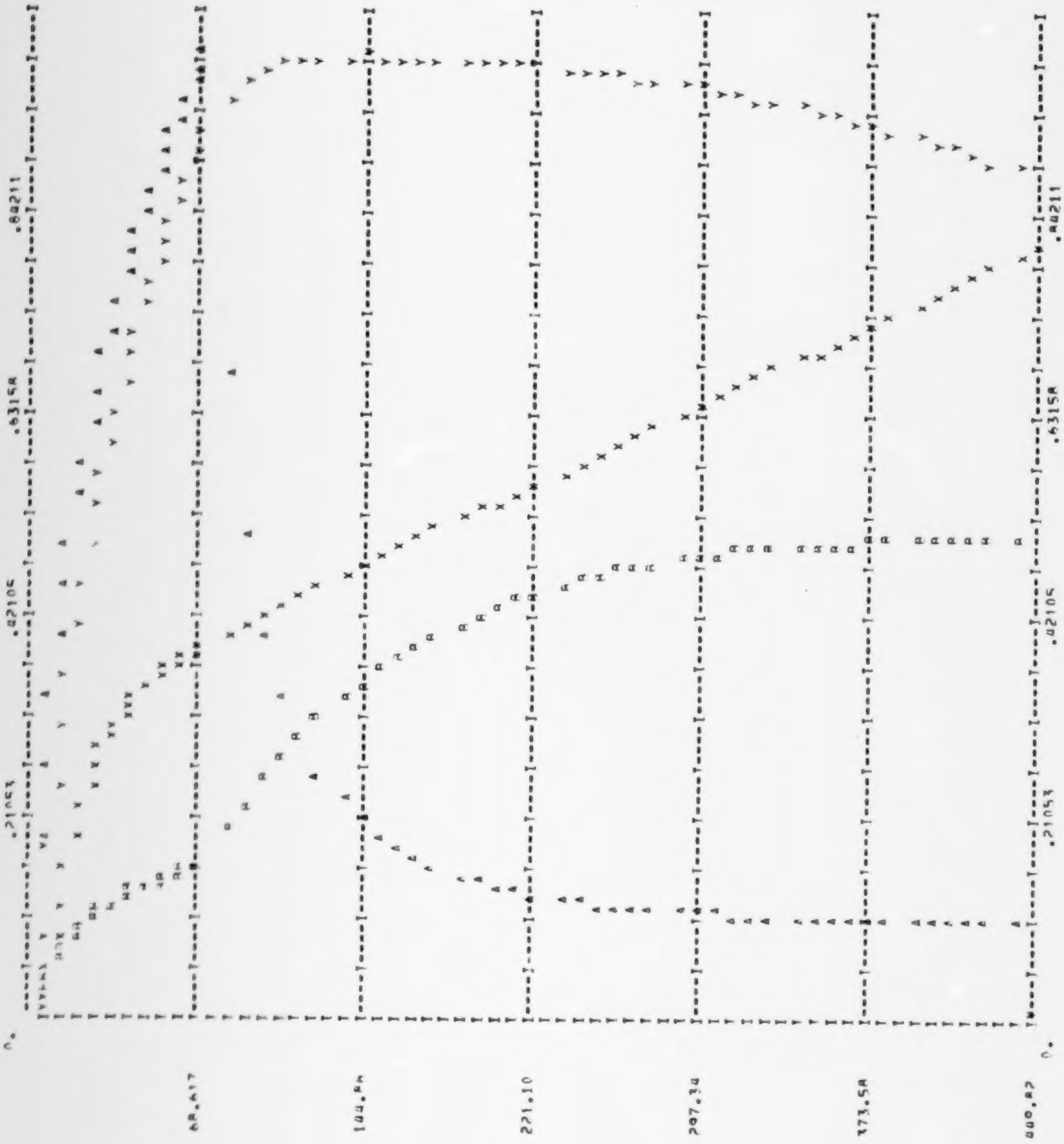
RUN D-2S-1

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                 0.                    75.916010
RANGE OF CONCENTRATIONS PLOTTED            0.                    .70000000
```



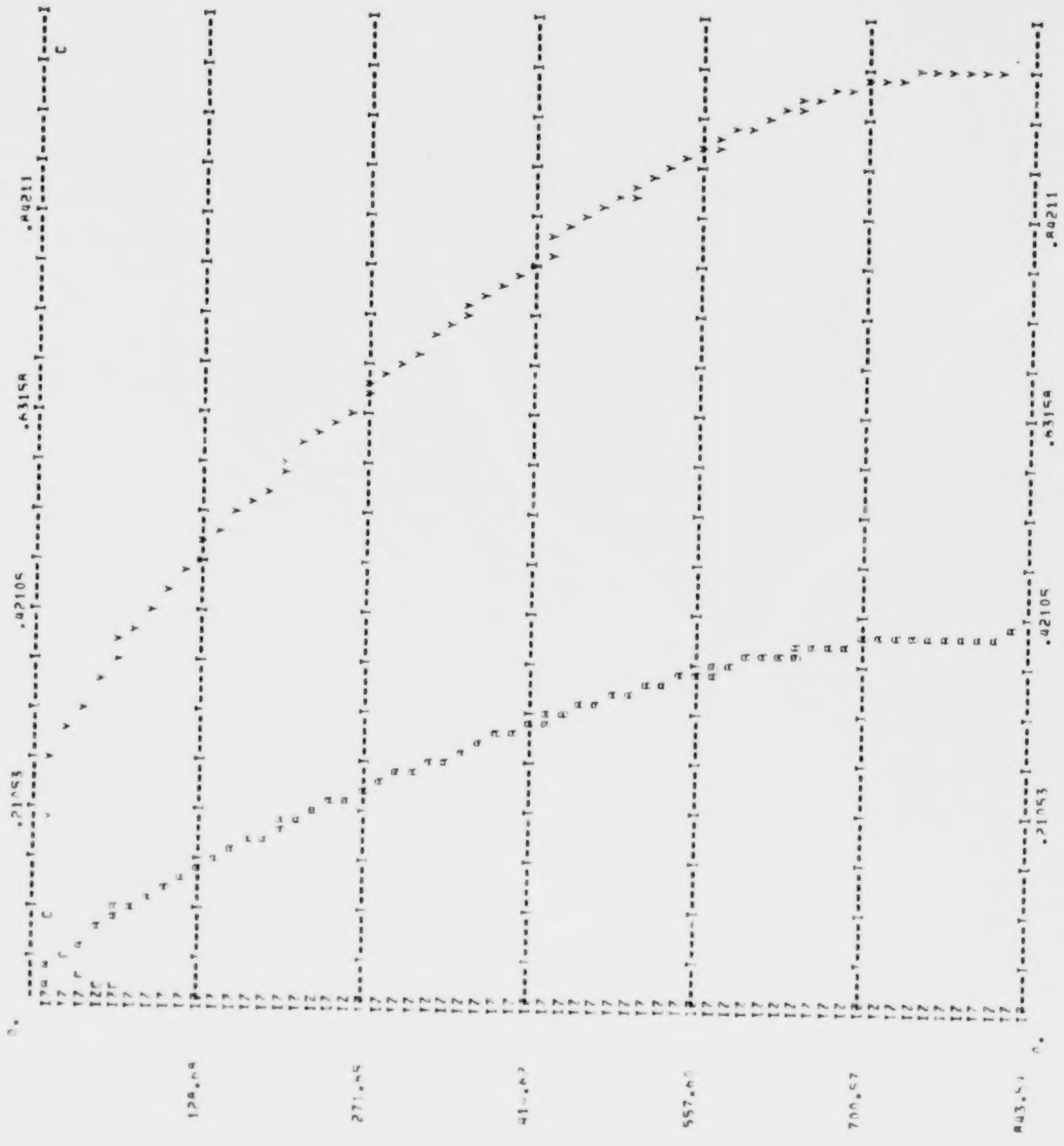
RUN D-2S-1

```
INDEPENDENT VARIABLE IS   TIME    OVER RANGE     0.          449.82

                         DEPENDENT VARIABLES

SYMBOL               A            B             X            Y
MAX PLOTTED      13.390        86.490        65.380       97.756
MIN PLOTTED      0.            0.            0.           0.
REMARKS          VERT. SIZE.   HOR. SIZE     HOR. DIST.   VERT. DIST.
```



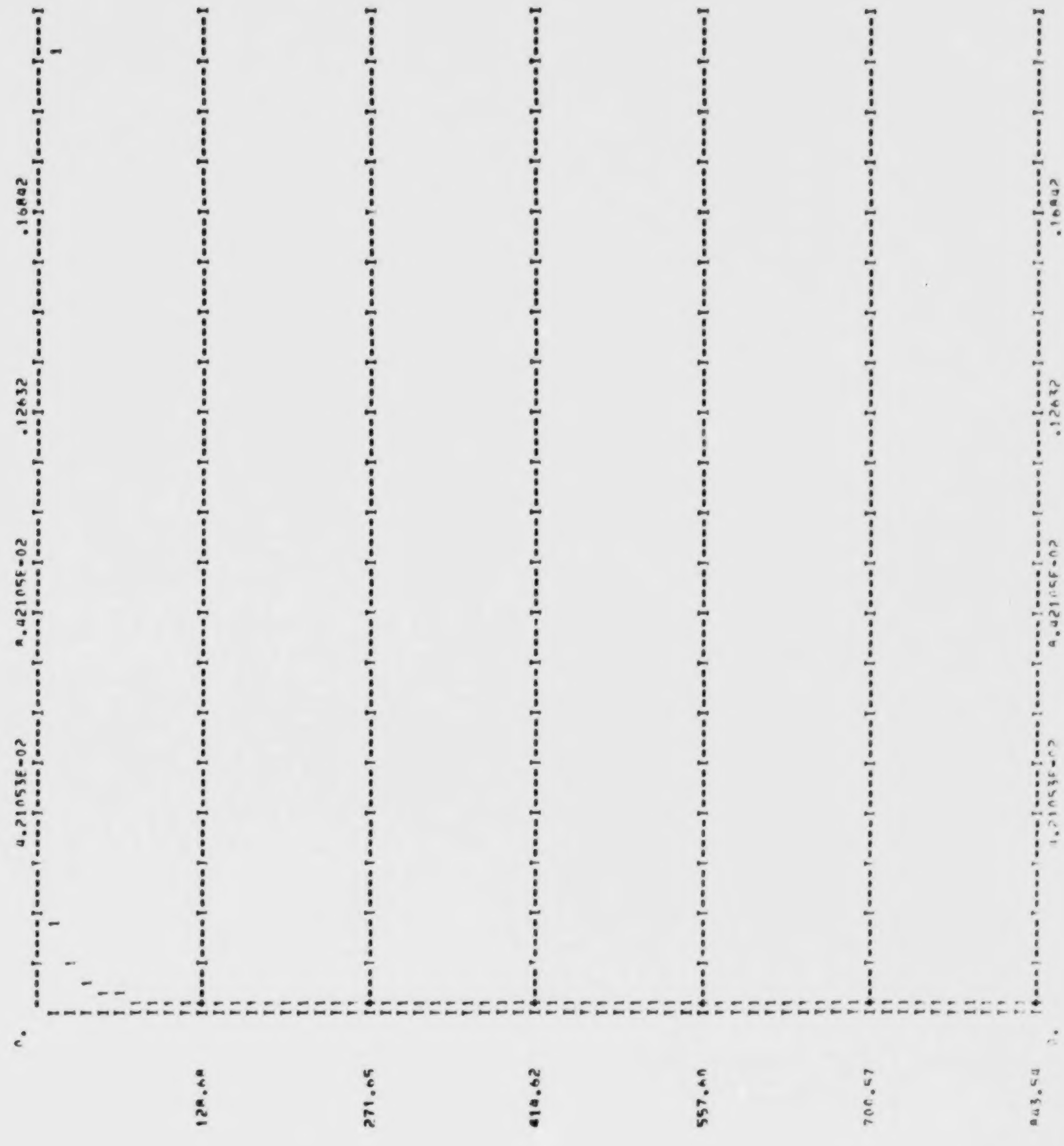
RUN J-L-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.            843.54

                        DEPENDENT VARIABLES

SYMBOL             Y             R               C             Z
MAX PLOTTED      51.654        15.217         .80000        0.
MIN PLOTTED      0.            0.             0.            0.
REMARKS          VERT. DIST.    RADIUS        FLUID CONC.    HOR. DIST.
```

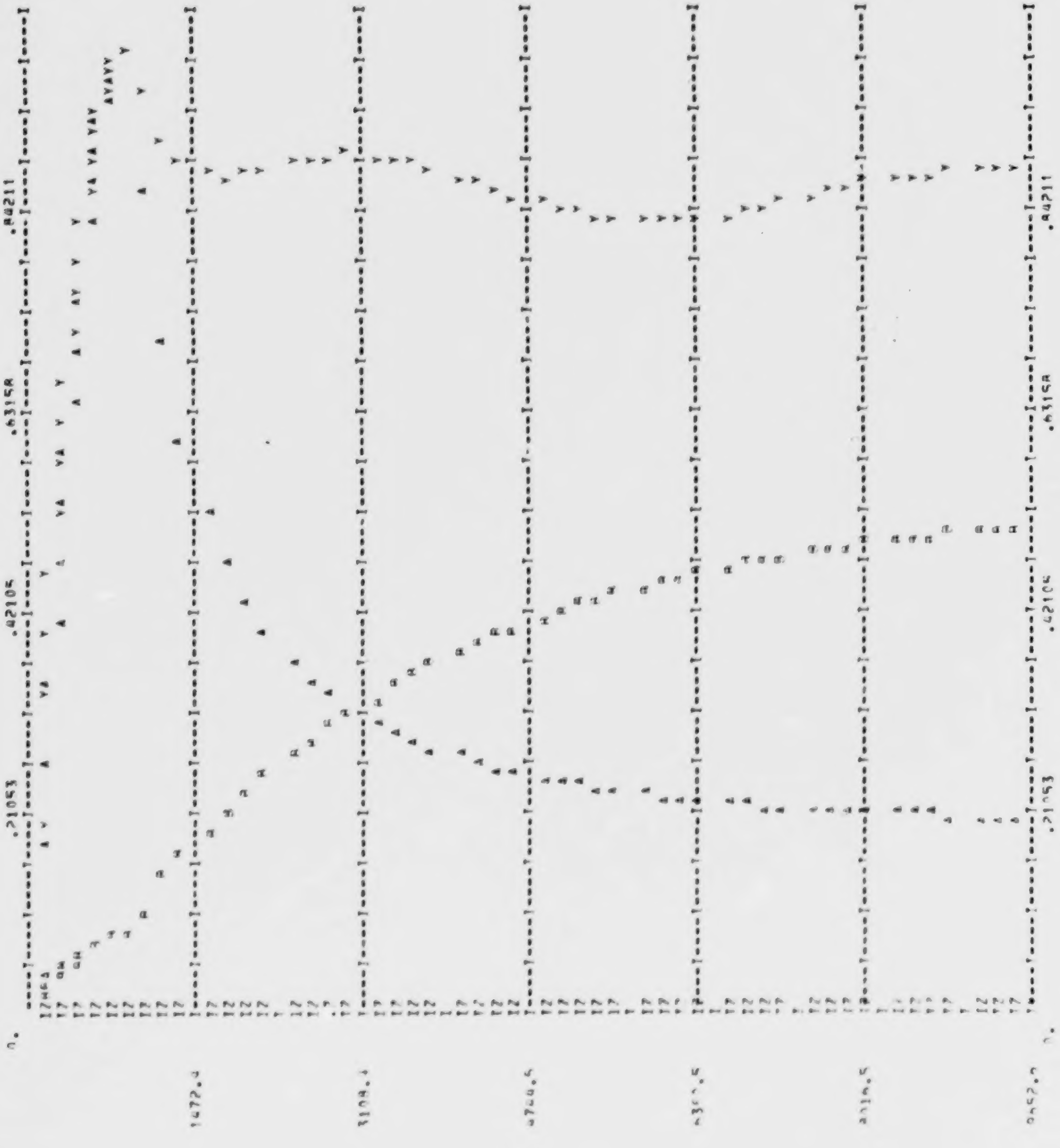


RUN J-L-1

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.              843.54147
RANGE OF CONCENTRATIONS PLOTTED         0.              .20000000
```



```
                         RUN J-L-1
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          9452.6

                    DEPENDENT VARIABLES

SYMBOL               A              B             Z              Y
MAX PLOTTED      15.217          96.814        0.             51.654
MIN PLOTTED      0.              0.            0.             0.
REMARKS          VERT. SIZE.     HOR. SIZE     HOR. DIST.     VERT. DIST.
```

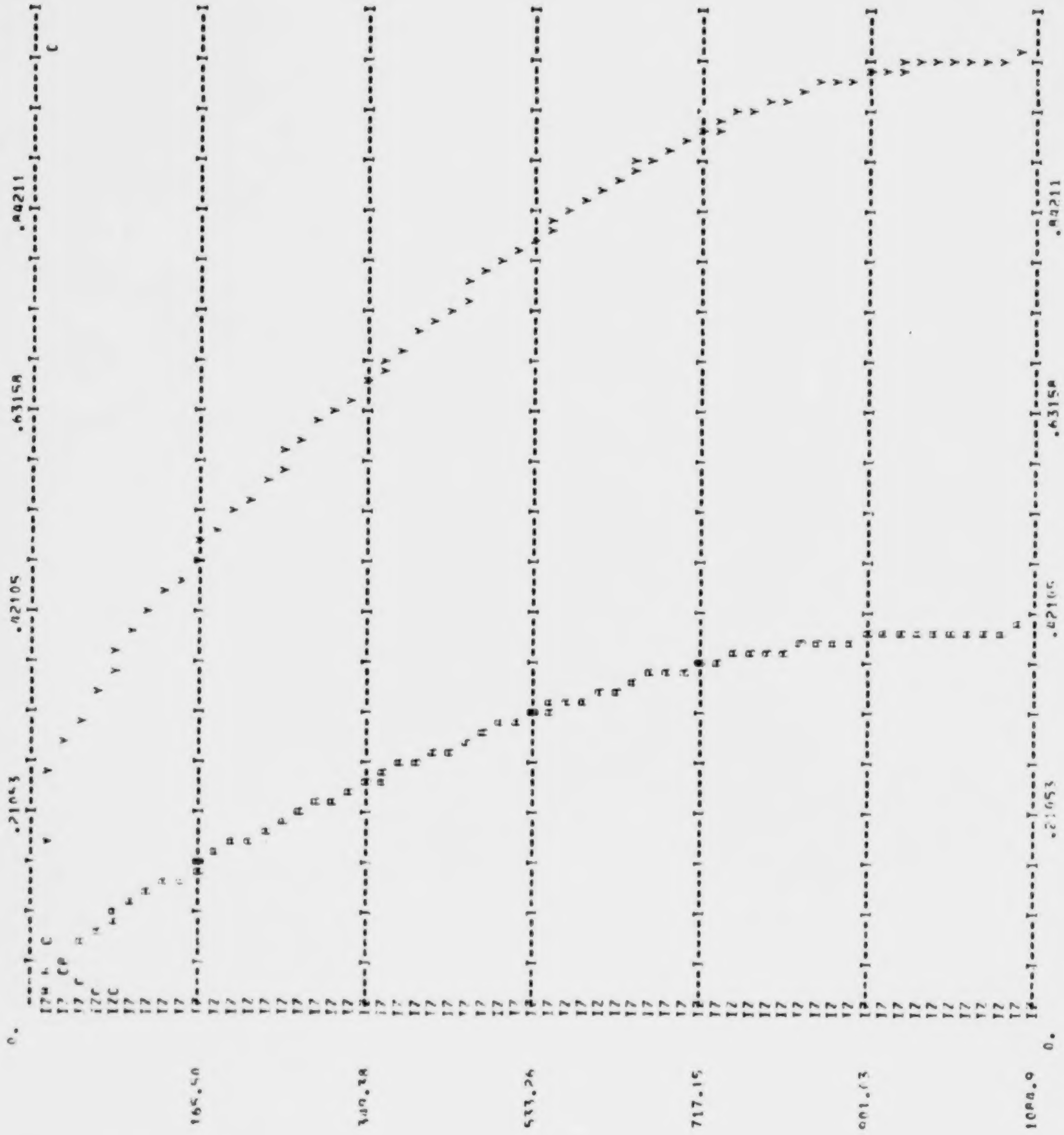


RUN J-L-2

INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE 0. 1084.9

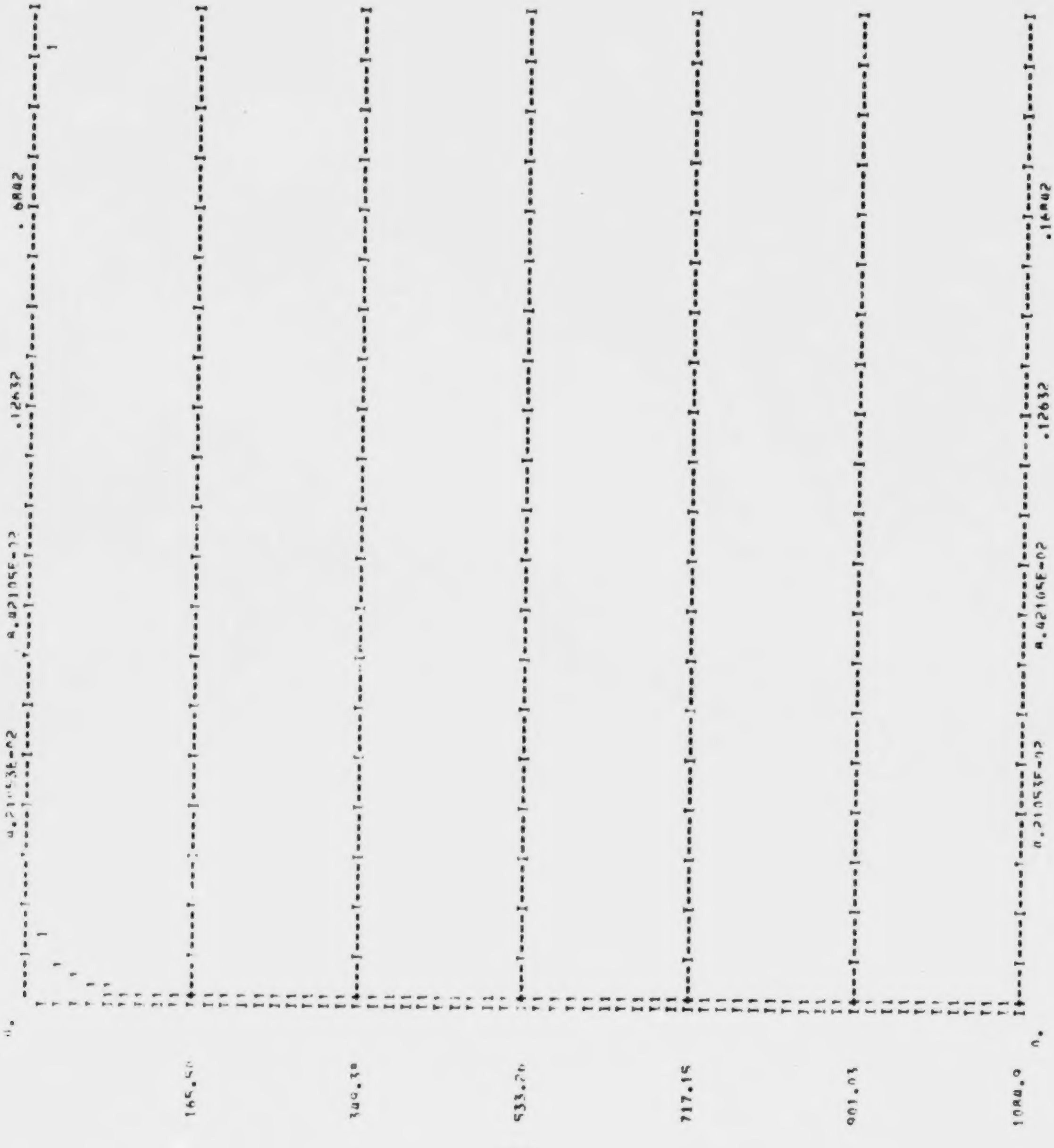
DEPENDENT VARIABLES

SYMBOL	Y	R	C	Z
MAX PLOTTED	57.349	17.291	.60000	0.
MIN PLOTTED	0.	0.	0.	0.
REMARKS	VERT. DIST.	RADIUS	FLUID CONC.	HOR. DIST.



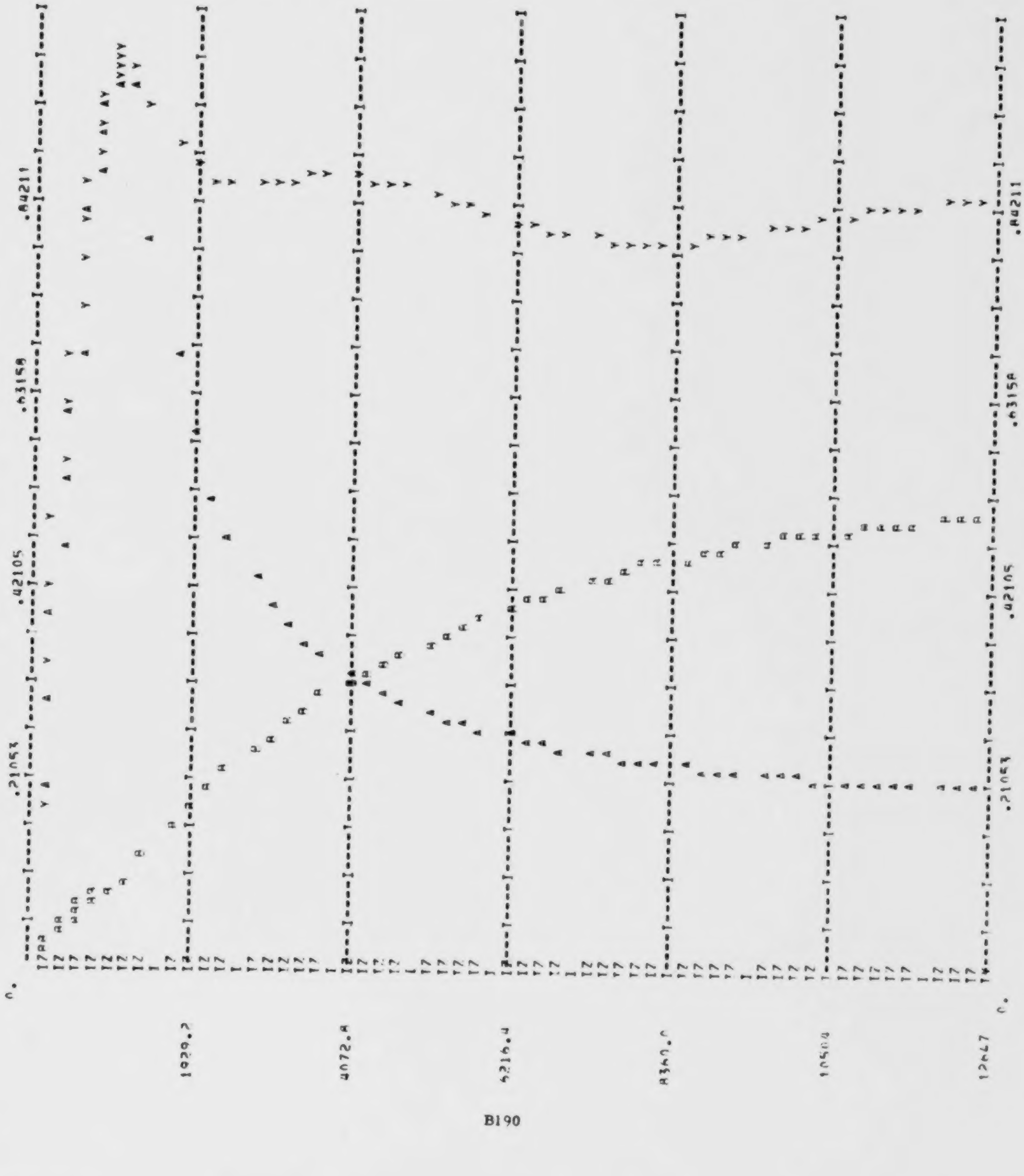
RUN J-L-2

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                   1084.9140
RANGE OF CONCENTRATIONS PLOTTED         0.                   .20000000
```



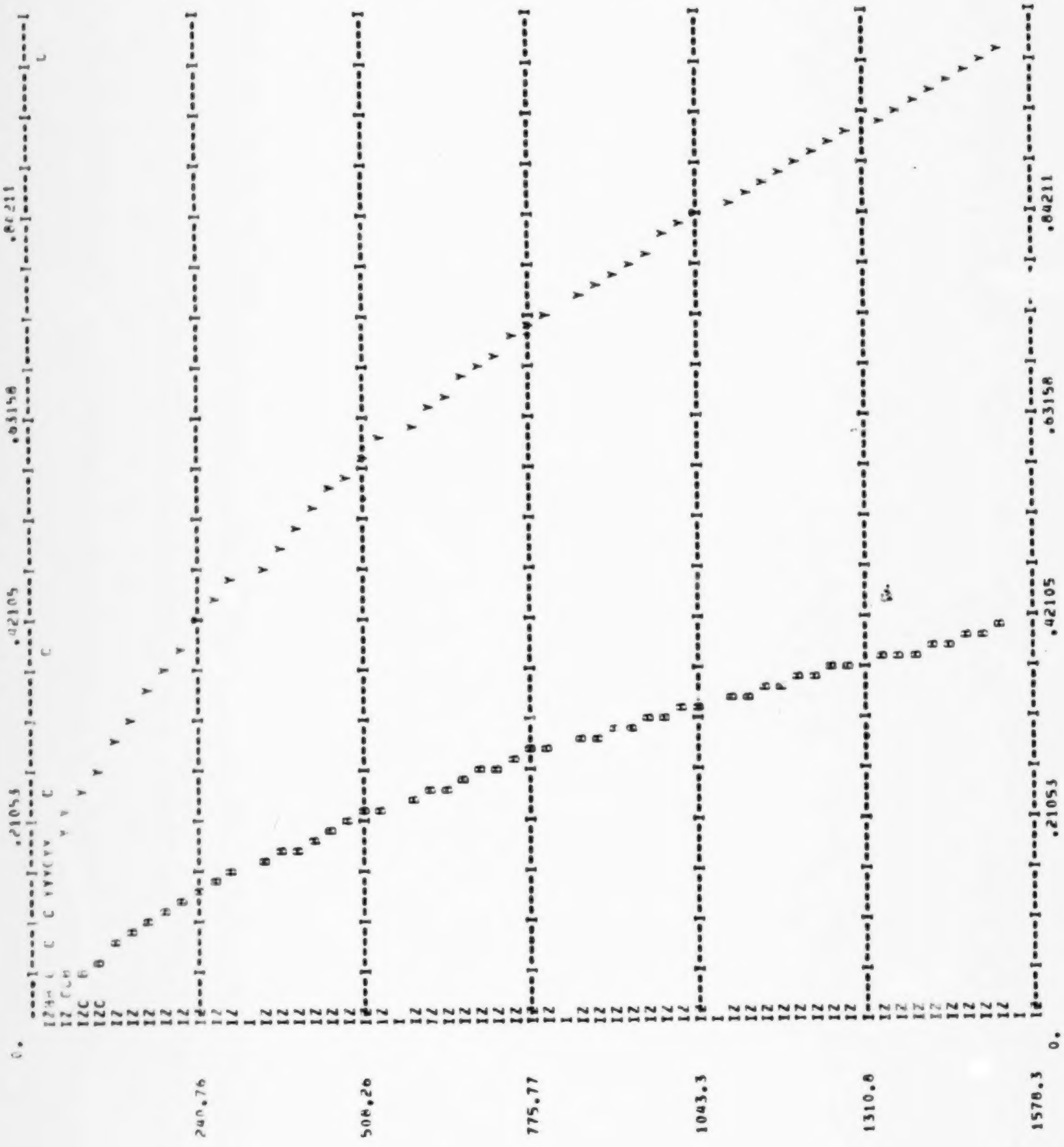
RUN J-L-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            12647

                       DEPENDENT VARIABLES

SYMBOL             A             B            Z            Y
MAX PLOTTED     17.277        109.19        0.           57.324
MIN PLOTTED     0.            0.            0.           0.
REMARKS         VERT. SIZE.   HOR. SIZE    HOR. DIST.   VERT. DIST.
```



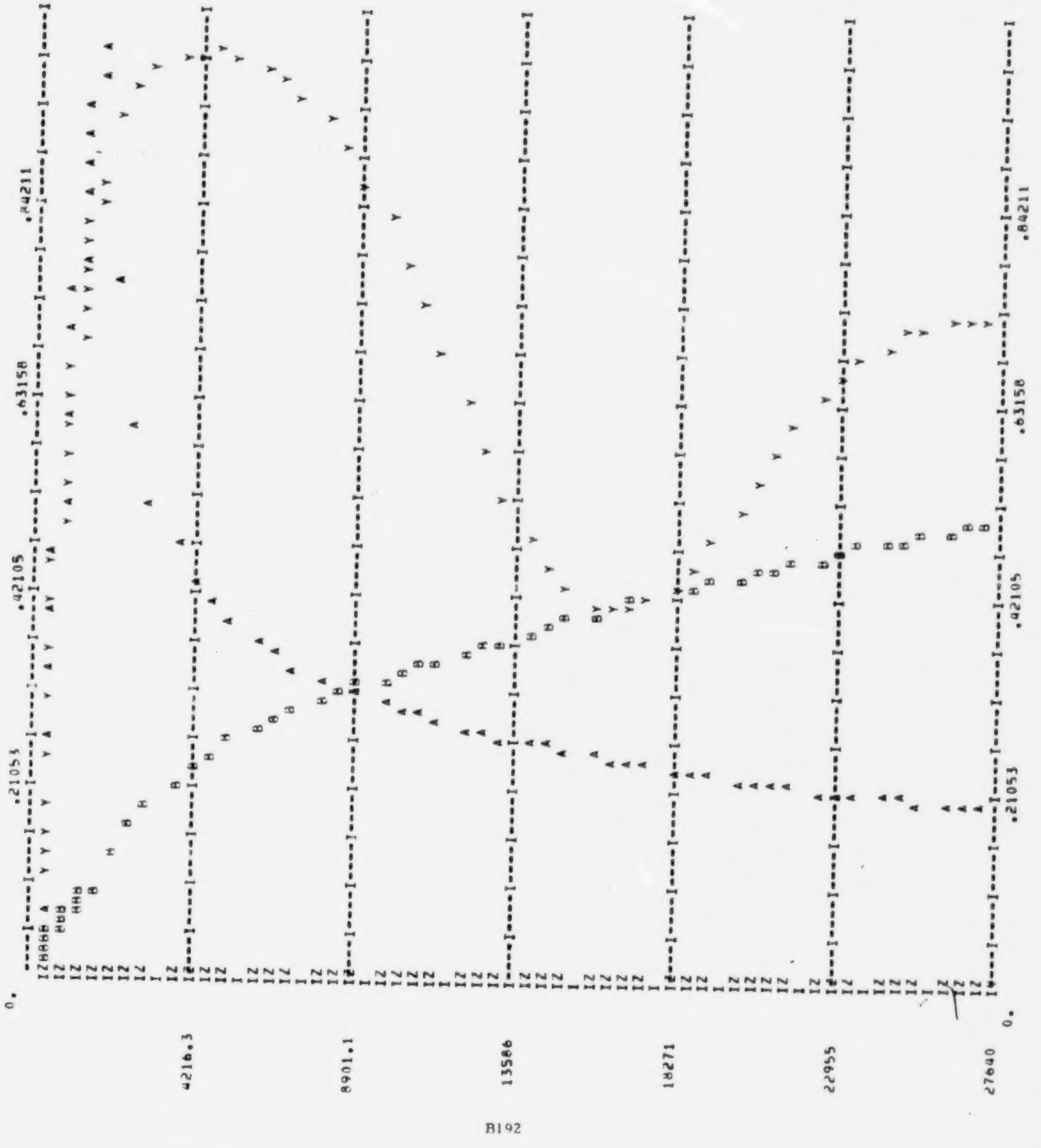
RUN J-L-3

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1578.3

                          DEPENDENT VARIABLES

SYMBOL              Y              B              C              Z
MAX PLOTTED     78.325         24.768         .80000          0.
MIN PLOTTED     0.             0.             0.              0.
REMARKS         VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



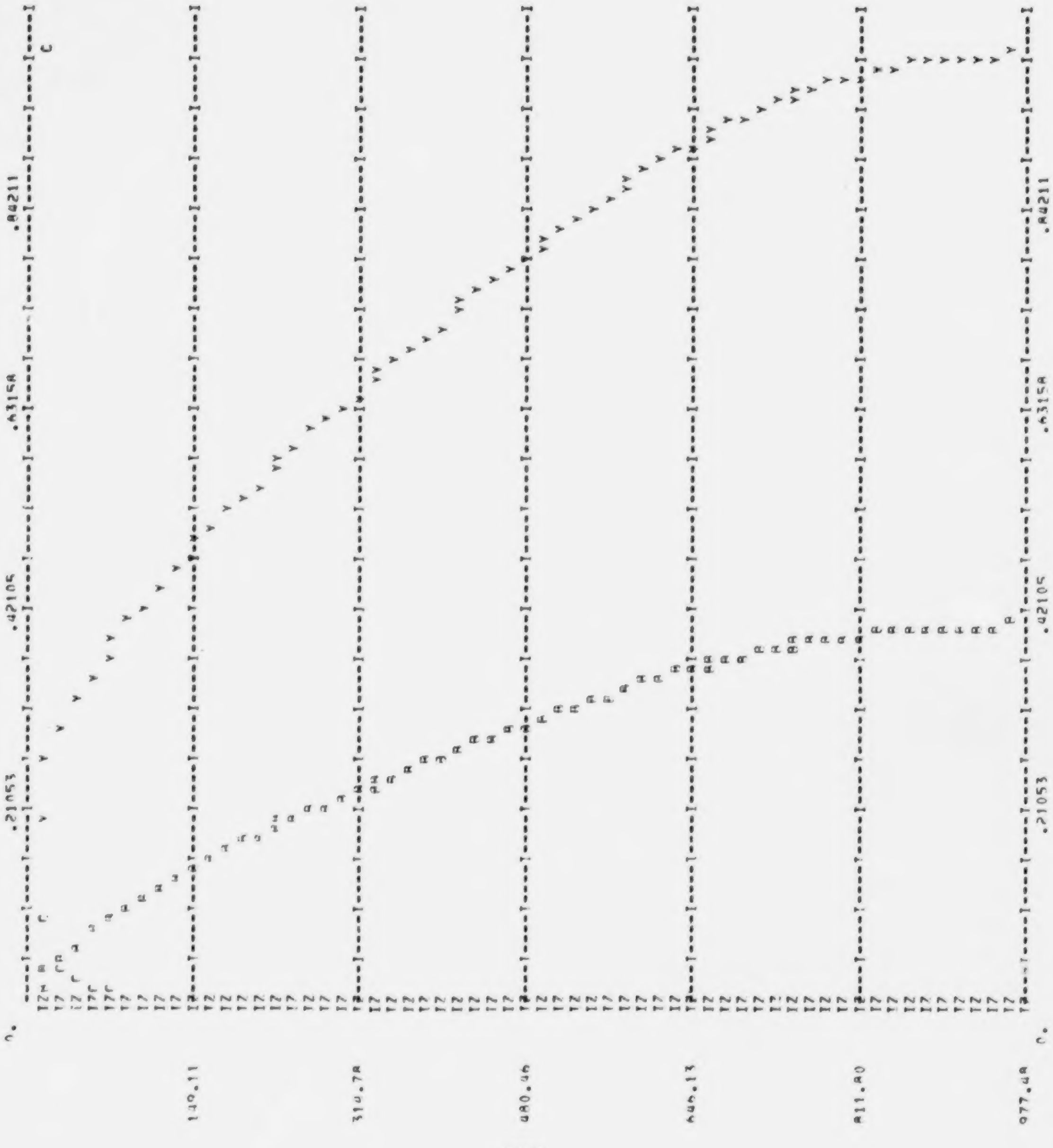
RUN J-L-3

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.           27640

                        DEPENDENT VARIABLES

SYMBOL              A              B            Z              Y
MAX PLOTTED      24.679         131.40        0.            90.887
MIN PLOTTED      0.             0.            0.            0.
REMARKS          VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



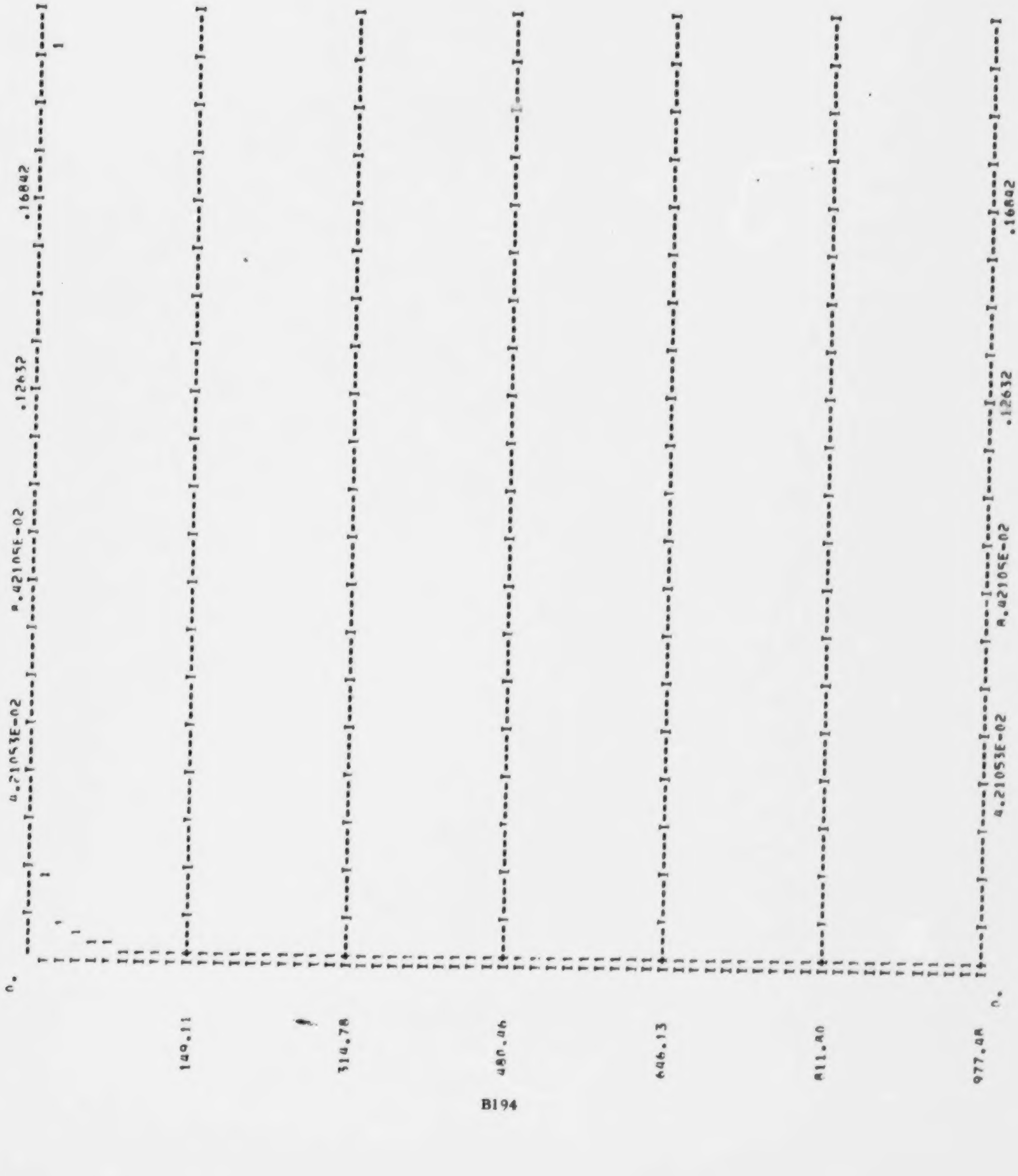
RUN J-L-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          977.48

                         DEPENDENT VARIABLES

SYMBOL              Y              R              C              Z
MAX PLOTTED      50.828         14.953         .80000         0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



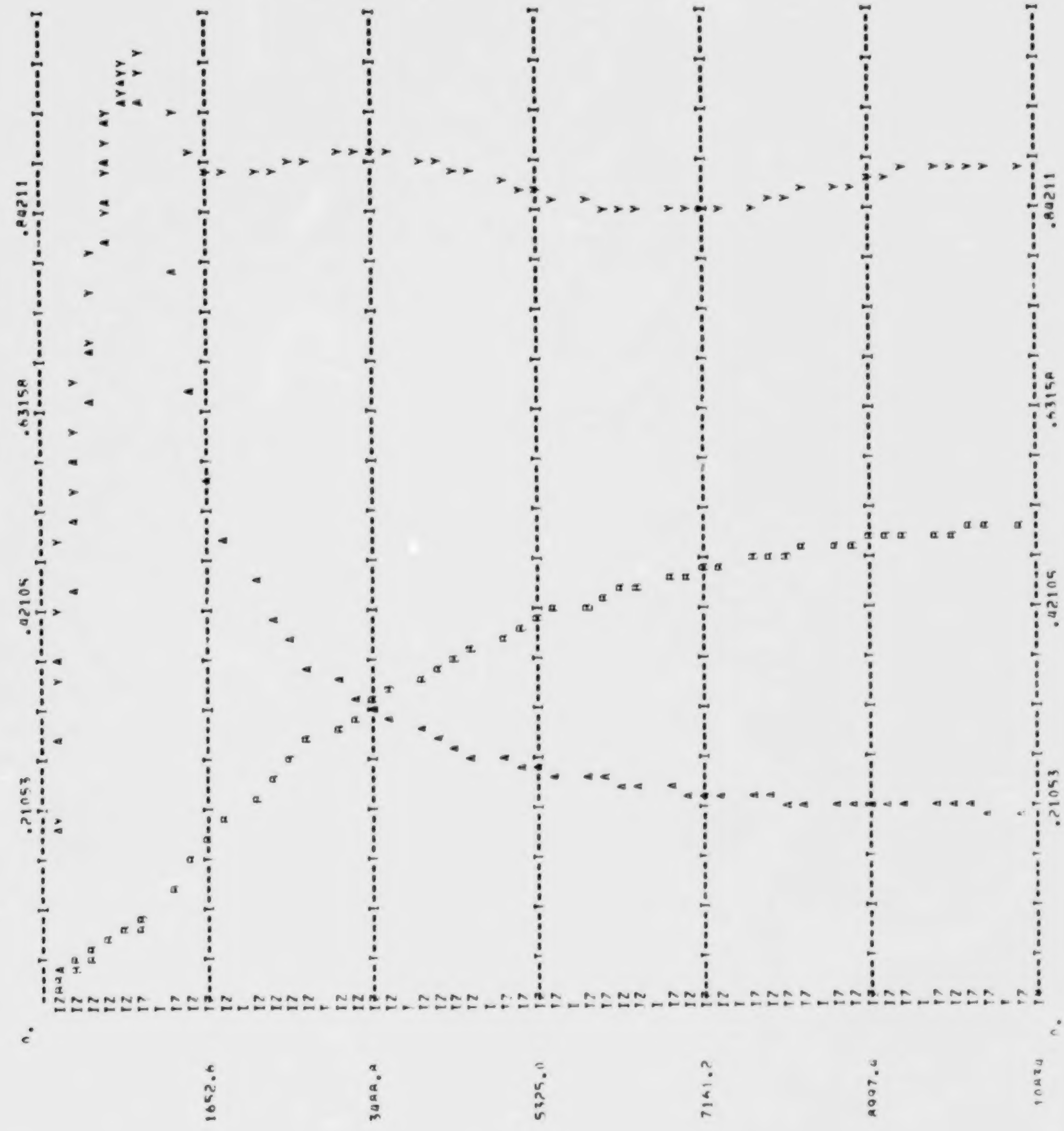
RUN J-L-4

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.              977.47878
RANGE OF CONCENTRATIONS PLOTTED         0.              .20000000
```



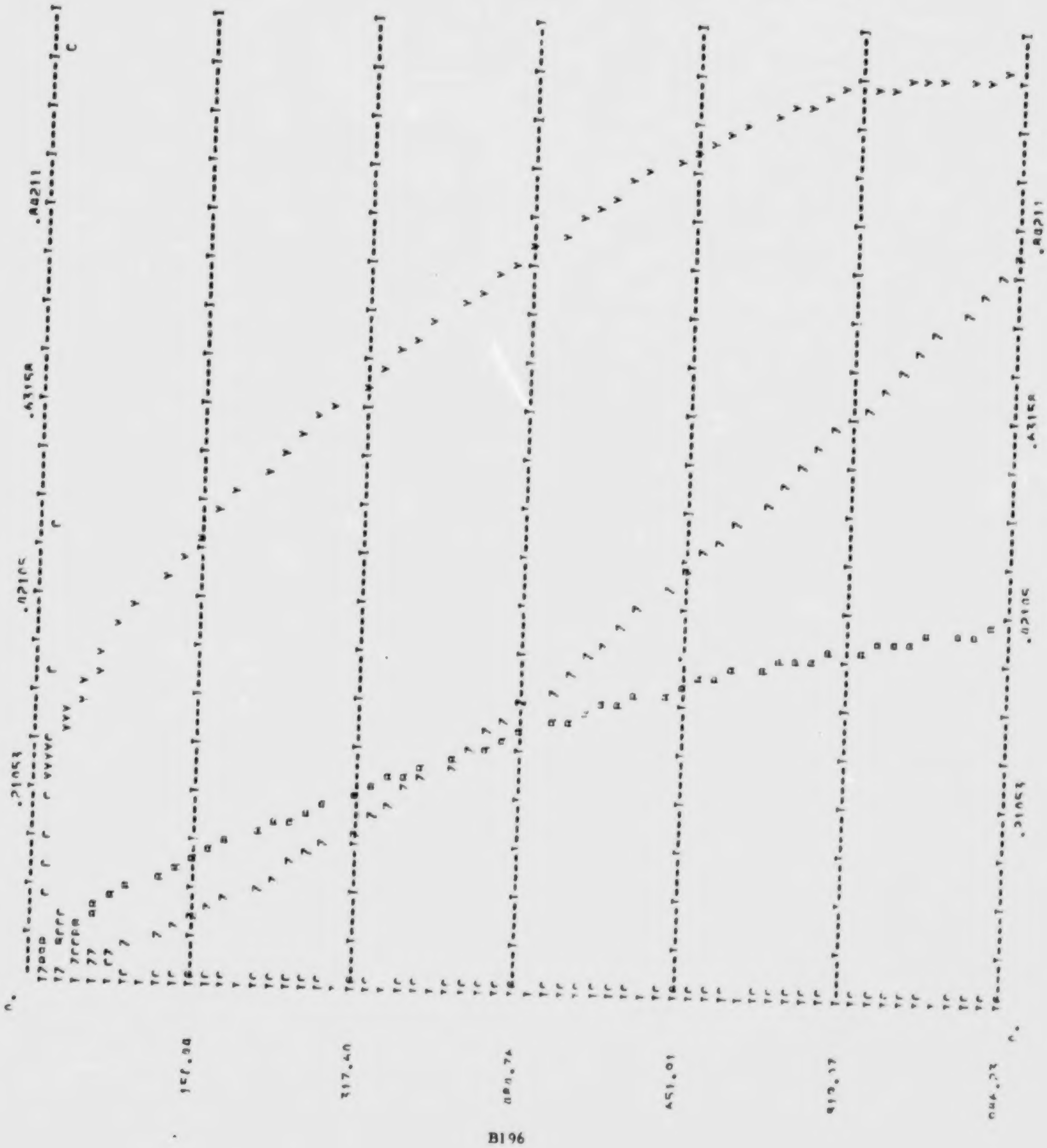
RUN J-L-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            10834

                    DEPENDENT VARIABLES

SYMBOL              A              B            Z              Y
MAX PLOTTED     14.936         94.614       0.             50.802
MIN PLOTTED    0.             0.            0.            0.
REMARKS        VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



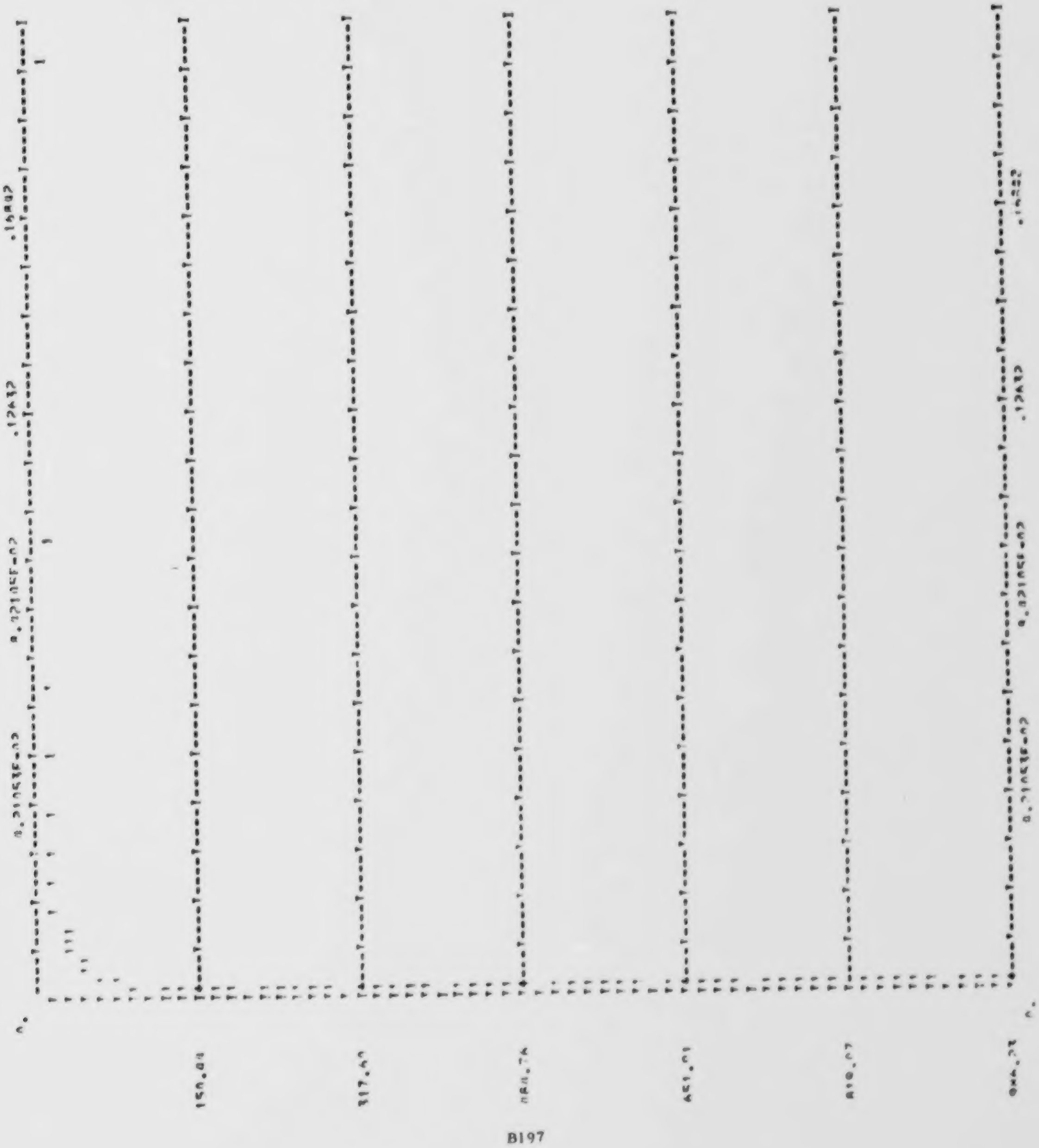
RUN J-L-5

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          986.23

                    DEPENDENT VARIABLES

SYMBOL                  Y              R              C              Z
MAX PLOTTED         50.127         16.180         .80000         72.322
MIN PLOTTED         0.             0.             0.             0.
REMARKS             VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



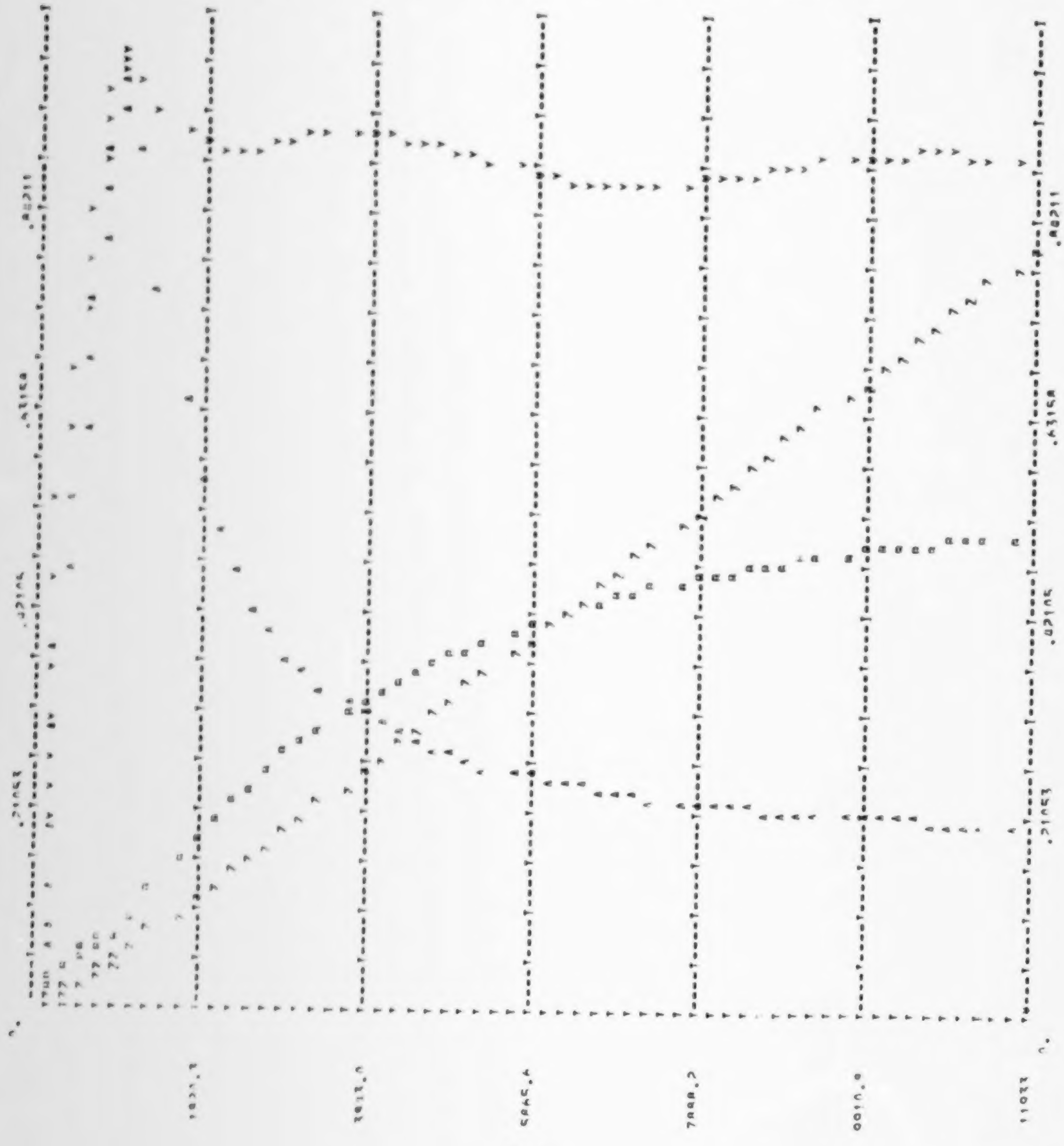
RUN J-L-5

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                 986.22587
RANGE OF CONCENTRATIONS PLOTTED         0.                 .20000000
```



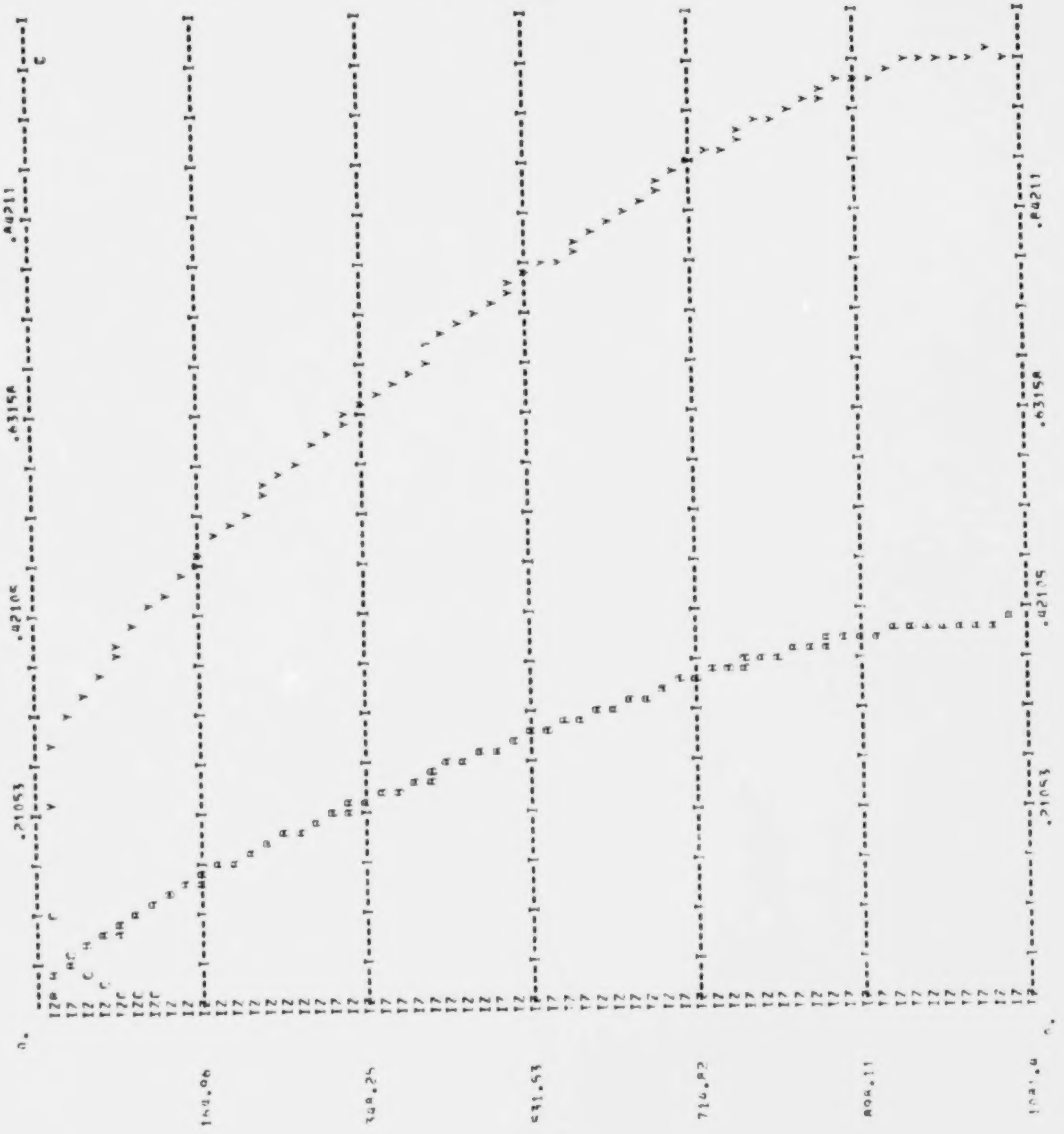
RUN J-L-5

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            11033

                    DEPENDENT VARIABLES

SYMBOL              A           B            Z            V
MAX PLOTTED      16.110      113.31       1208.0       50.130
MIN PLOTTED      0.          0.           0.           0.
REMARKS          VERT. SIZE. HOR. SIZE    HOR. DIST.   VERT. DIST.
```



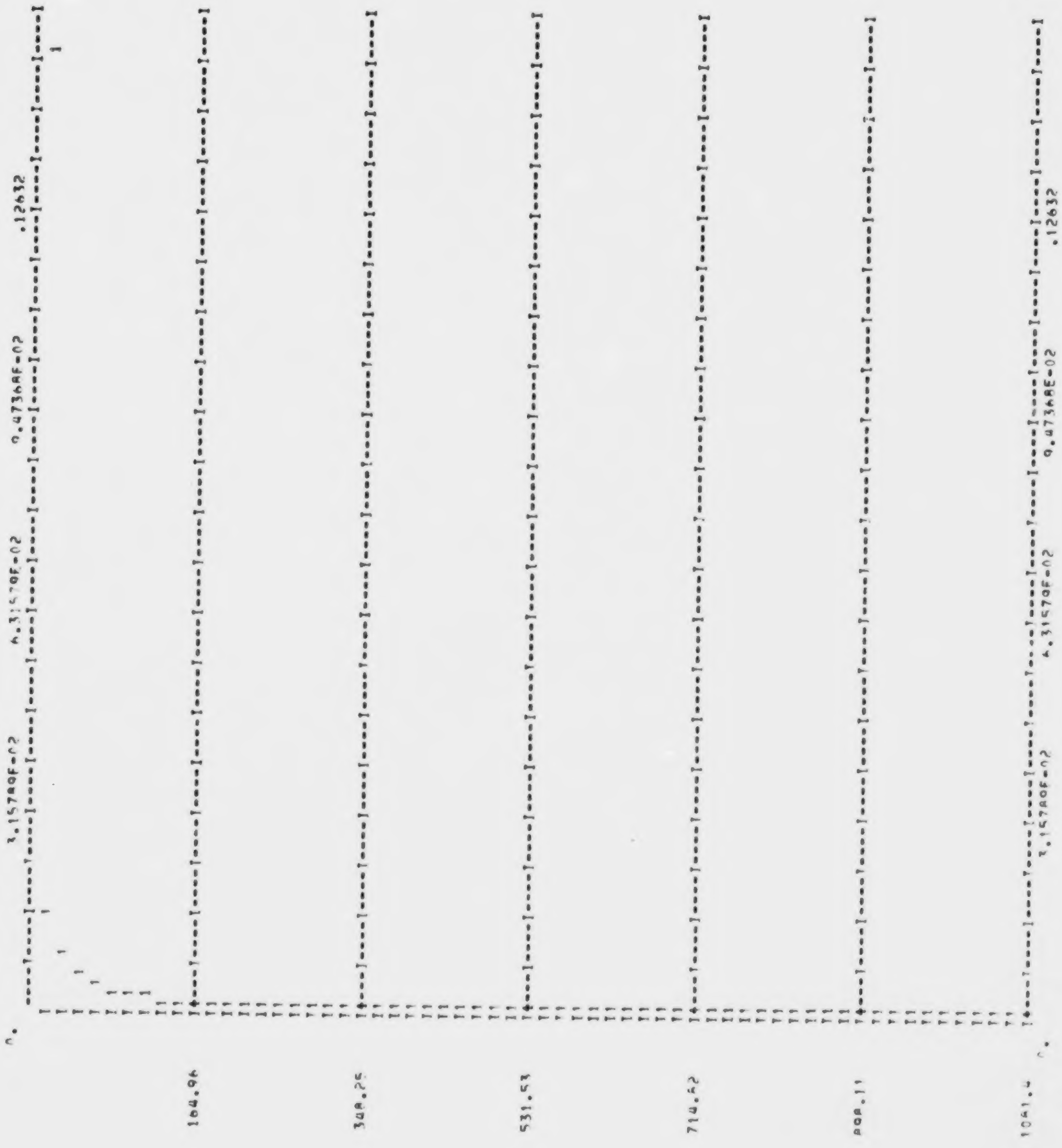
RUN J-S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1081.4

                        DEPENDENT VARIABLES

SYMBOL              Y             R             C             Z
MAX PLOTTED      46.360        13.423        .85000        0.
MIN PLOTTED      0.            0.            0.            0.
REMARKS          VERT. DIST.    RADIUS       FLUID CONC.   HOR. DIST.
```

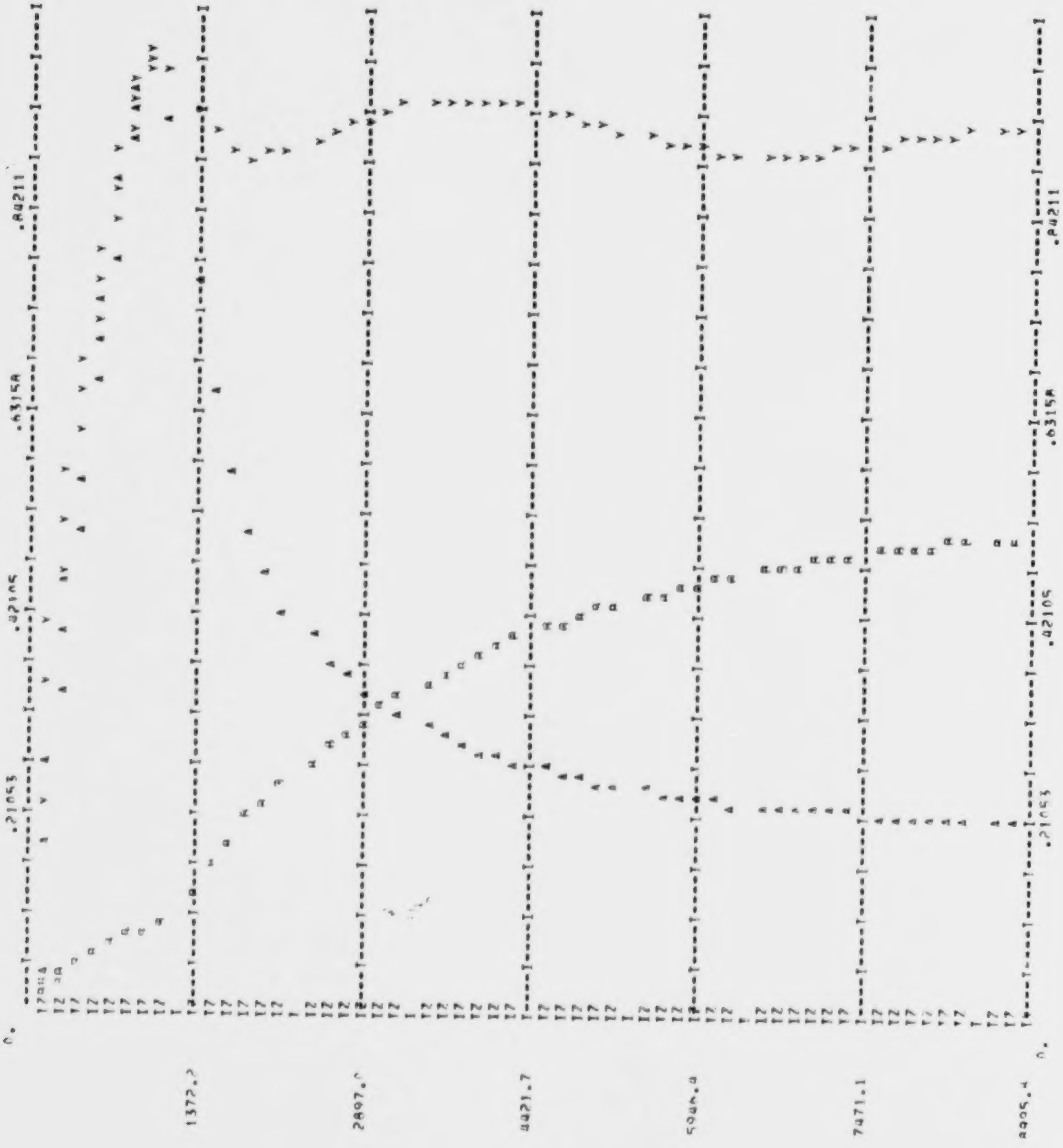


RUN J-S-1

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                1081.3942
RANGE OF CONCENTRATIONS PLOTTED         0.                .15000000
```

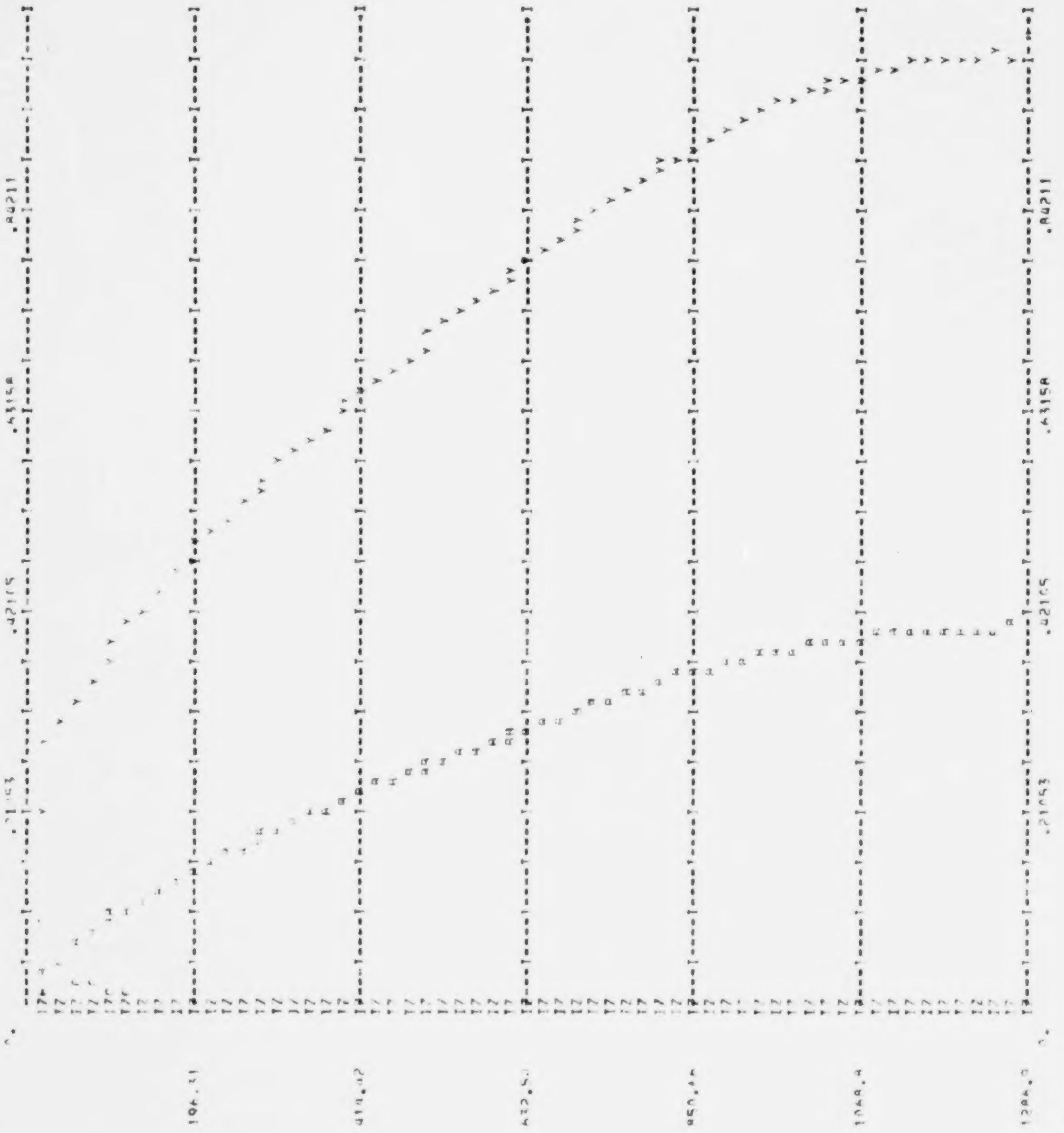


```
                              RUN J-S-1
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.            8995.8

                         DEPENDENT VARIABLES

SYMBOL              A              B              Z              Y
MAX PLOTTED      13.419         79.685         0.             46.360
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



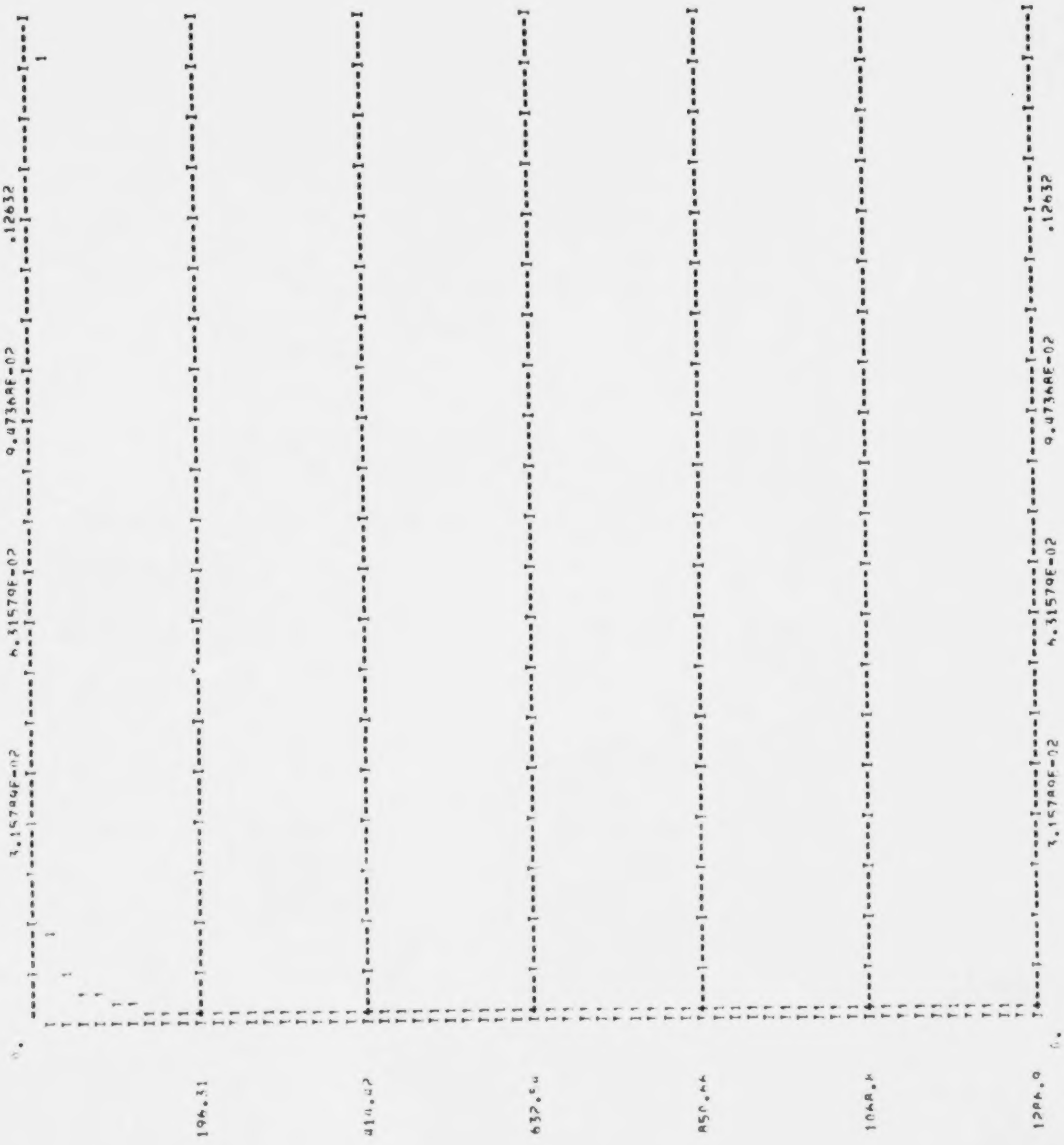
RUN J-S-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            1286.9

                         DEPENDENT VARIABLES

SYMBOL              Y               R              C             Z
MAX PLOTTED      89.379          14.586         .85000         0.
MIN PLOTTED      0.              0.             0.             0.
REMARKS          VERT. DIST.     RADIUS         FLUID CONC.    HOR. DIST.
```

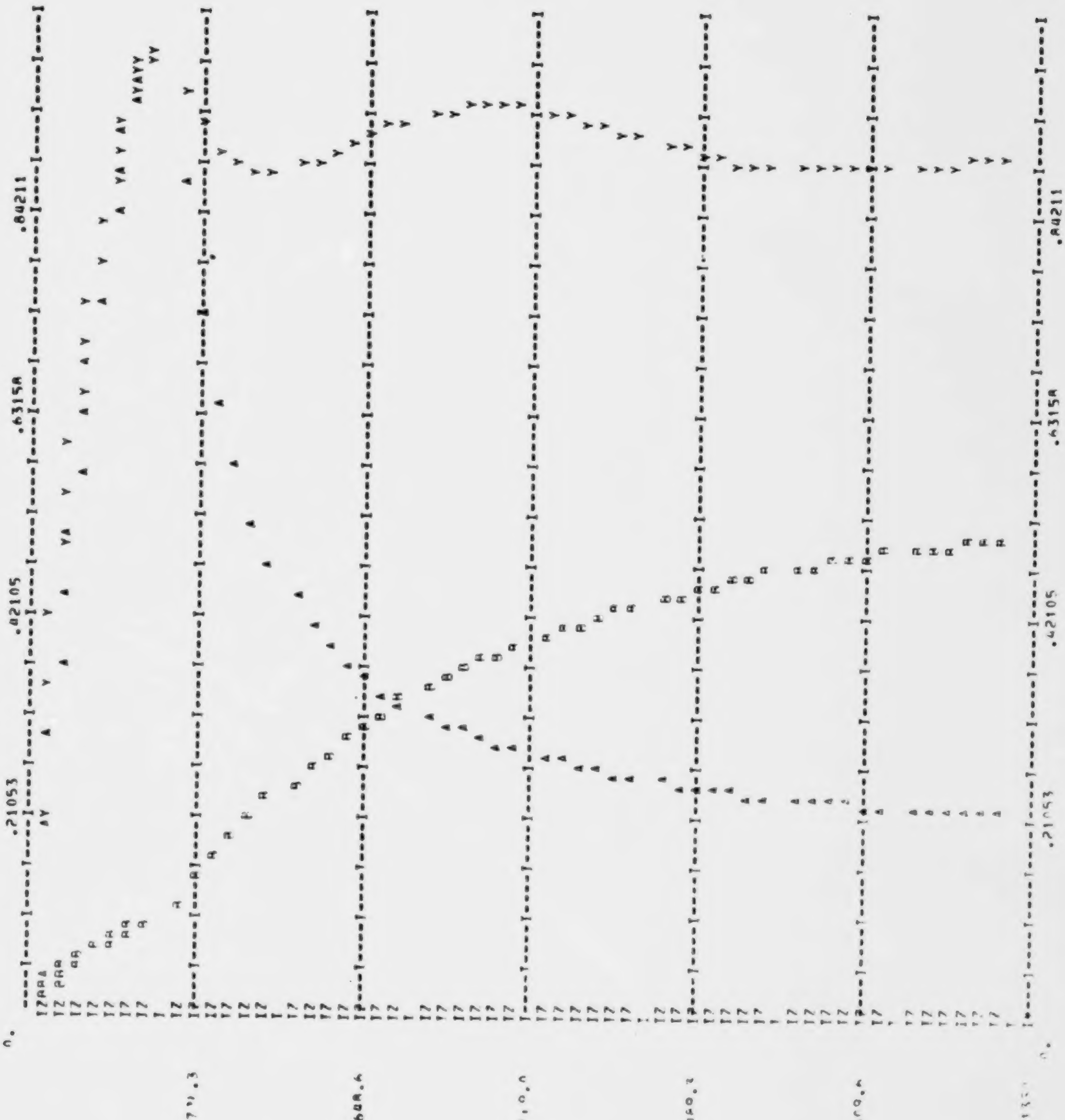


RUN J-S-2

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                                0.                  1286.8979
RANGE OF CONCENTRATIONS PLOTTED           0.                  .15000000
```

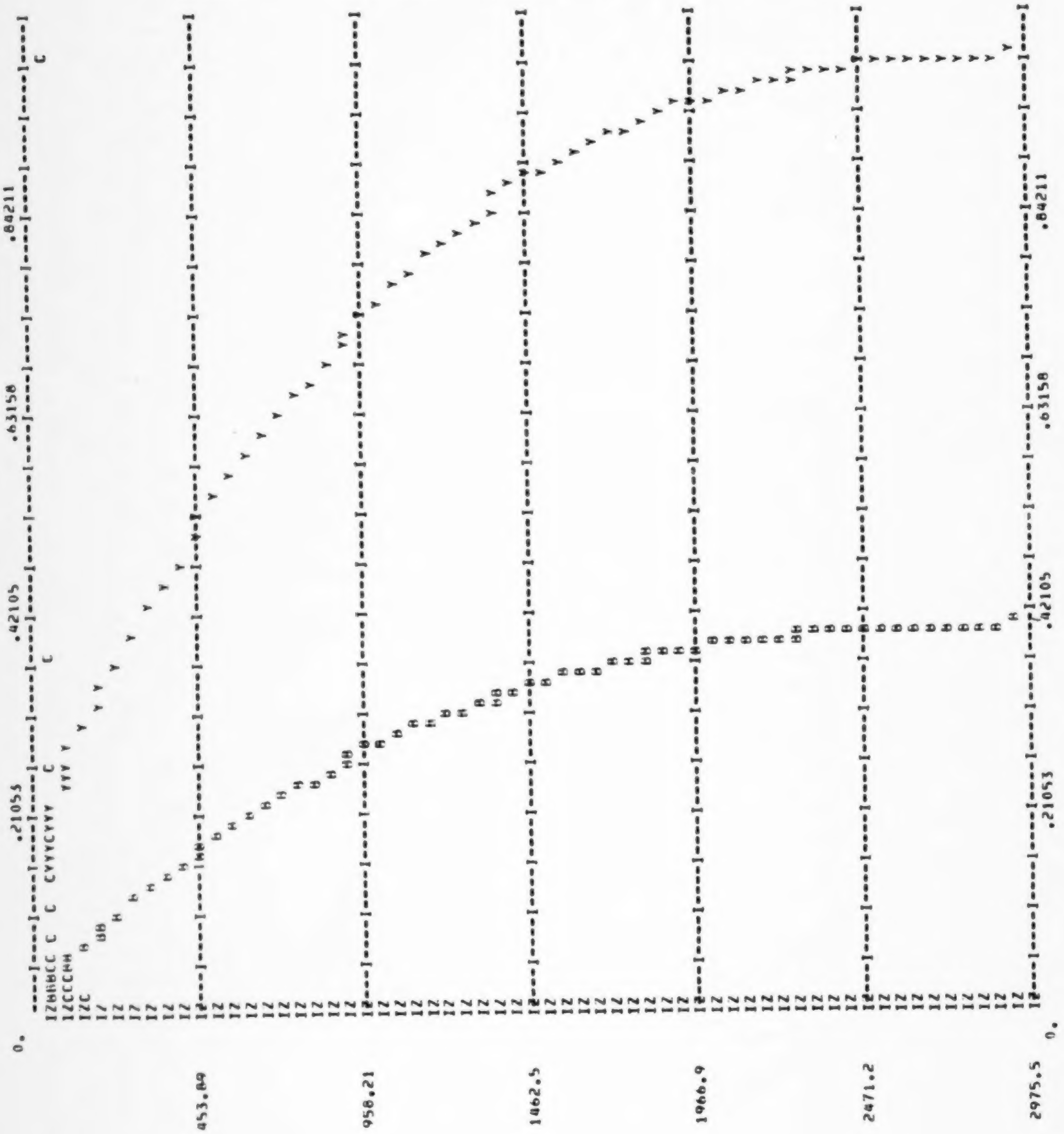


```
                                RUN J-S-2
     INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          11330

                          DEPENDENT VARIABLES

     SYMBOL            A              B            Z            Y
     MAX PLOTTED     14.560         84.531        0.         49.326
     MIN PLOTTED     0.             0.            0.         0.
     REMARKS         VERT. SIZE.    HOR. SIZE    HOR. DIST.   VERT. DIST.
```



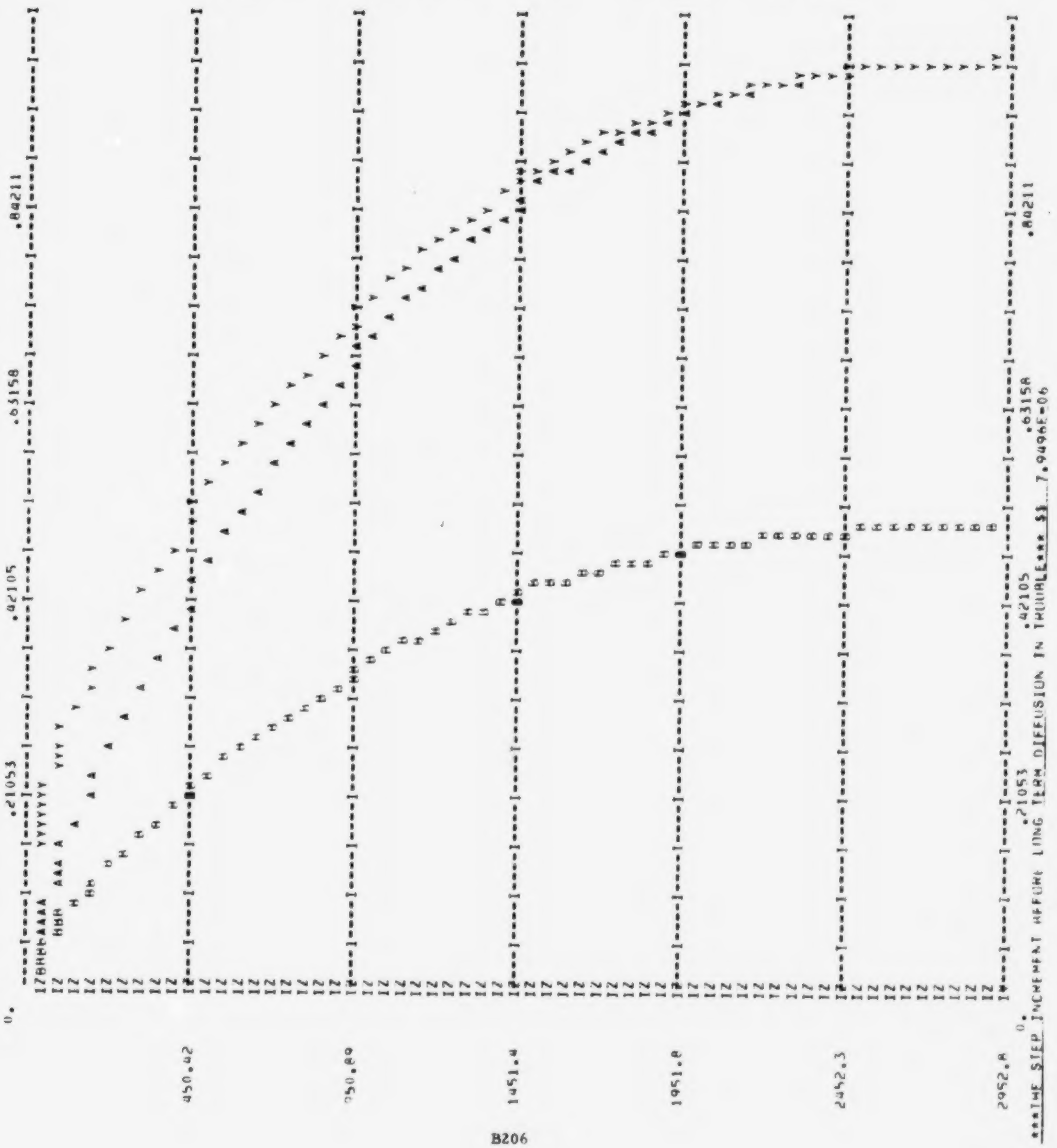
RUN J-S-3

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          2975.5

                         DEPENDENT VARIABLES

SYMBOL              Y              B               C             Z
MAX PLOTTED      66.804         20.351          .85000          0.
MIN PLOTTED      0.             0.              0.              0.
REMARKS          VERT. DIST.    RADIUS          FLUID CONC.     HOR. DIST.
```



RUN J-S-3

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.           2952.8

                         DEPENDENT VARIABLES

SYMBOL                A               B               Z               Y
MAX PLOTTED       20.351          20.351          0.              66.804
MIN PLOTTED       0.              0.              0.              0.
REMARKS           VERT. SIZE.     HOR. SIZE       HOR. DIST.      VERT. DIST.
```



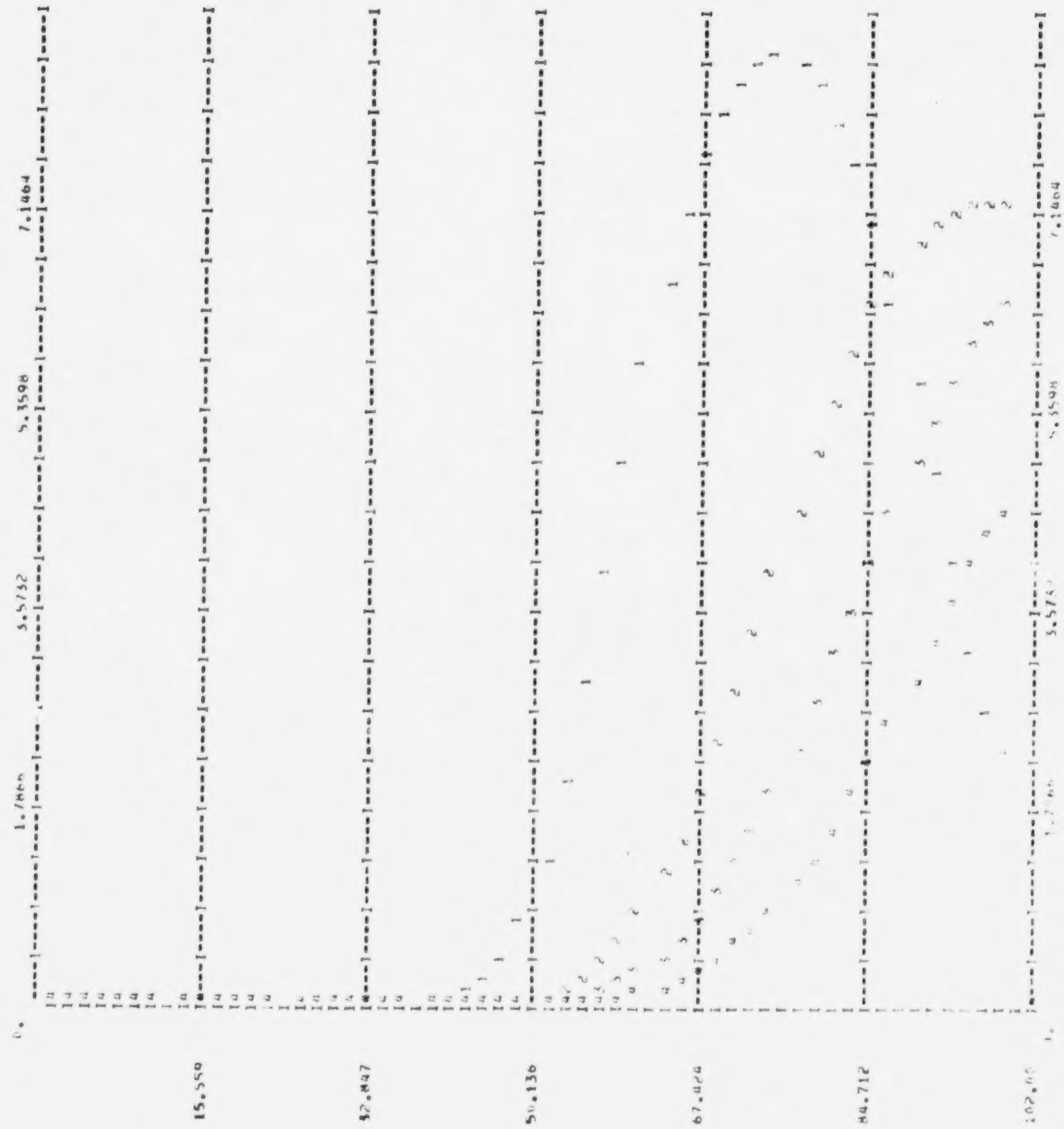
THE STEP INCREMENT BEFORE LONG TERM DIFFUSION IN TROUBLE $$ 7.9496E-06

RUN J-S-3

GRAPH OF COD VS Y AT TIMES

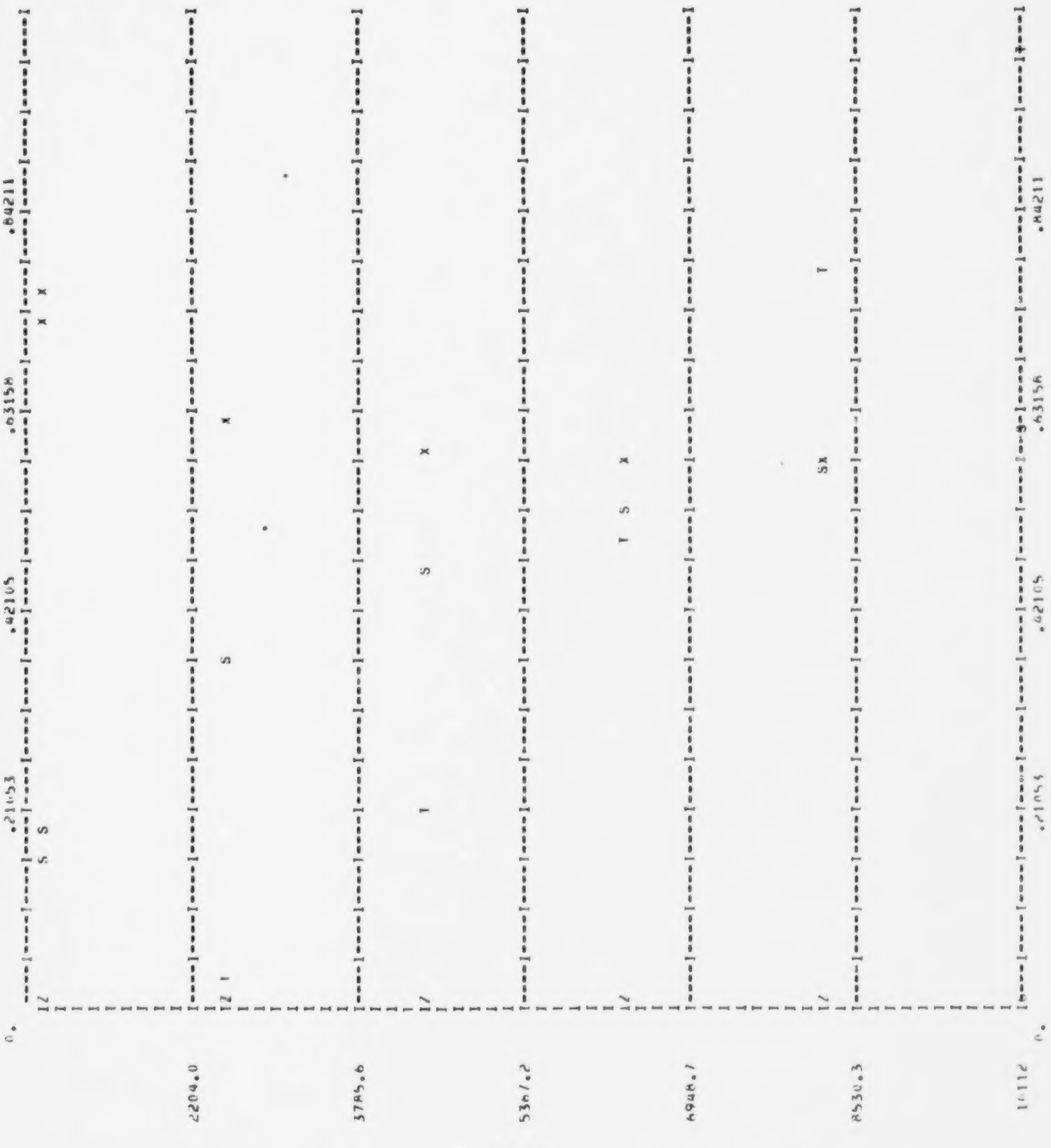
2584.2199 6348.0253 8229.9286 10111.831

RANGE OF Y PLOTTED 0. 102.00000
RANGE OF COD PLOTTED 0. 8.4862953



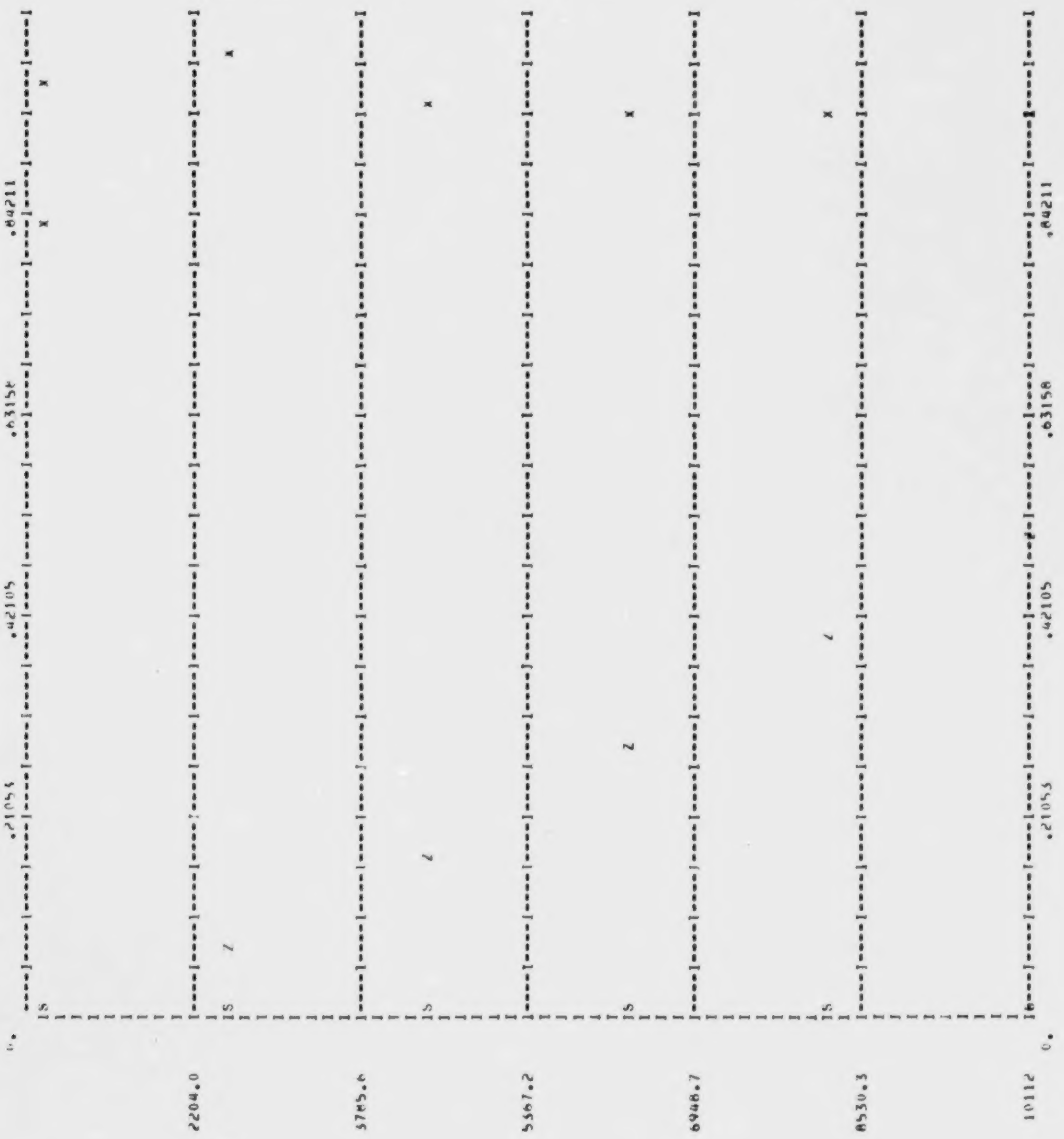
RUN J-S-3

```
PLOT OF TOT BDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE              780.63393          10111.851
MAXIMUM T,X,Z,S         225.96701          6335.3487         0.                814.06739
MINIMUM T,X,Z,S        0.                 .0.                0.               0.
```



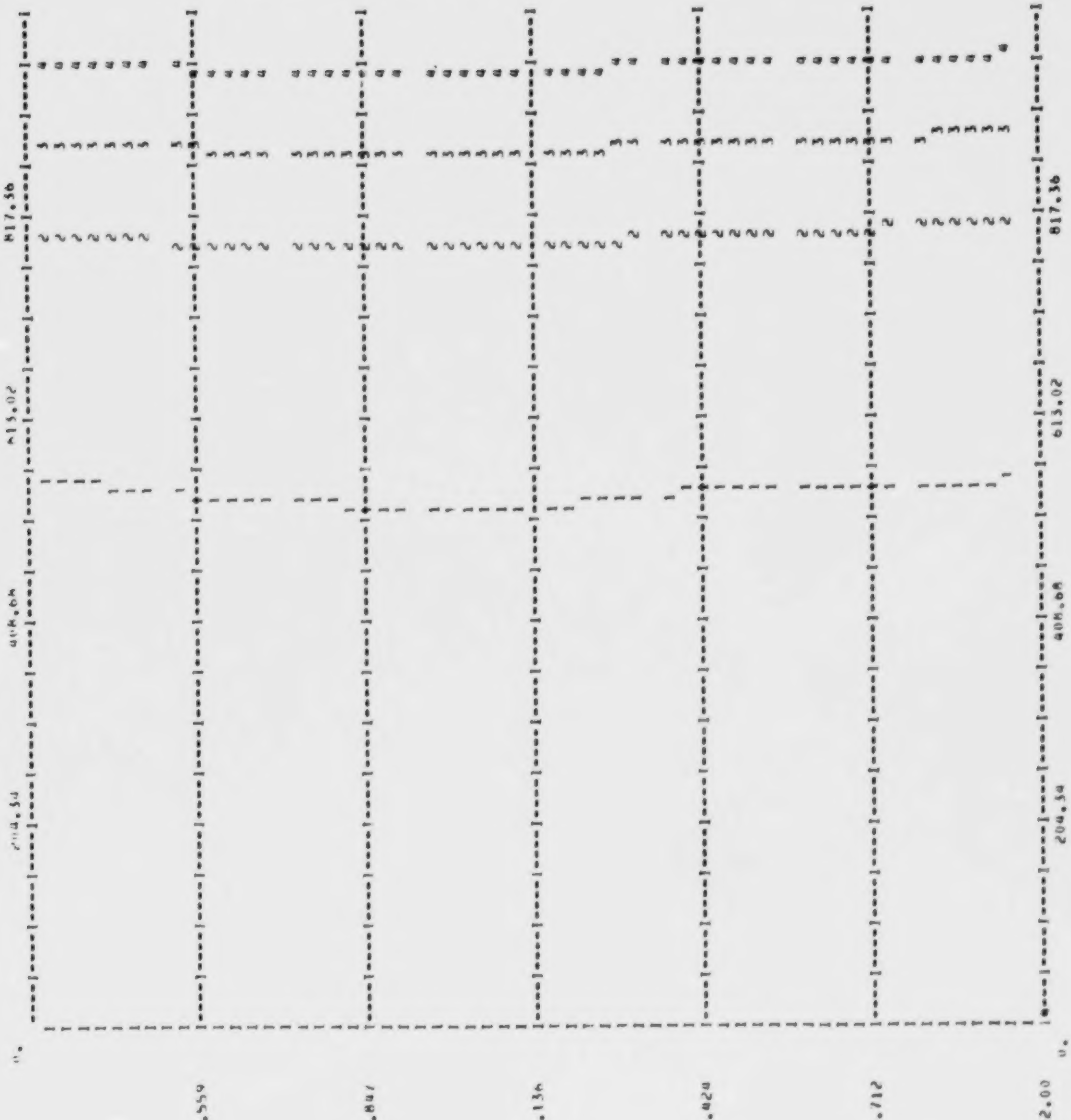
RUN J-S-3

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

TIME RANGE=          780.63393          10111.831
MAXIMUM X,Z,S        1232342.7          23636.354          0.
MINIMUM X,Z,S       0.                 0.                  0.
```



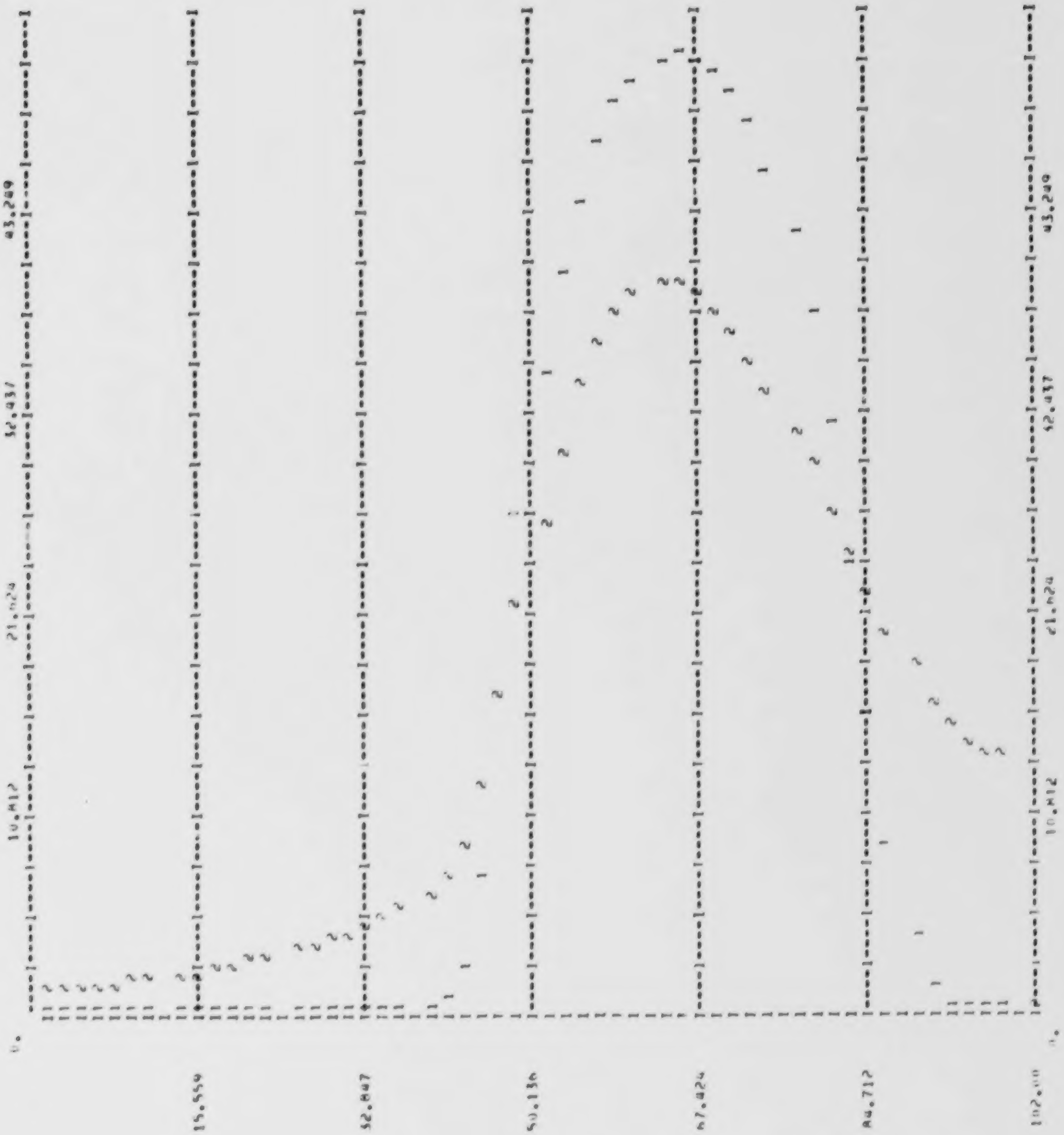
RUN J-S-3

```
                         GRAPH OF   SIZE  VS Y AT TIMES
2584.2199                6348.0253        8229.9280          10111.831

      RANGE OF    Y   PLOTTED        0.                     102.00000
      RANGE OF  SIZE  PLOTTED        0.                     970.61126
```



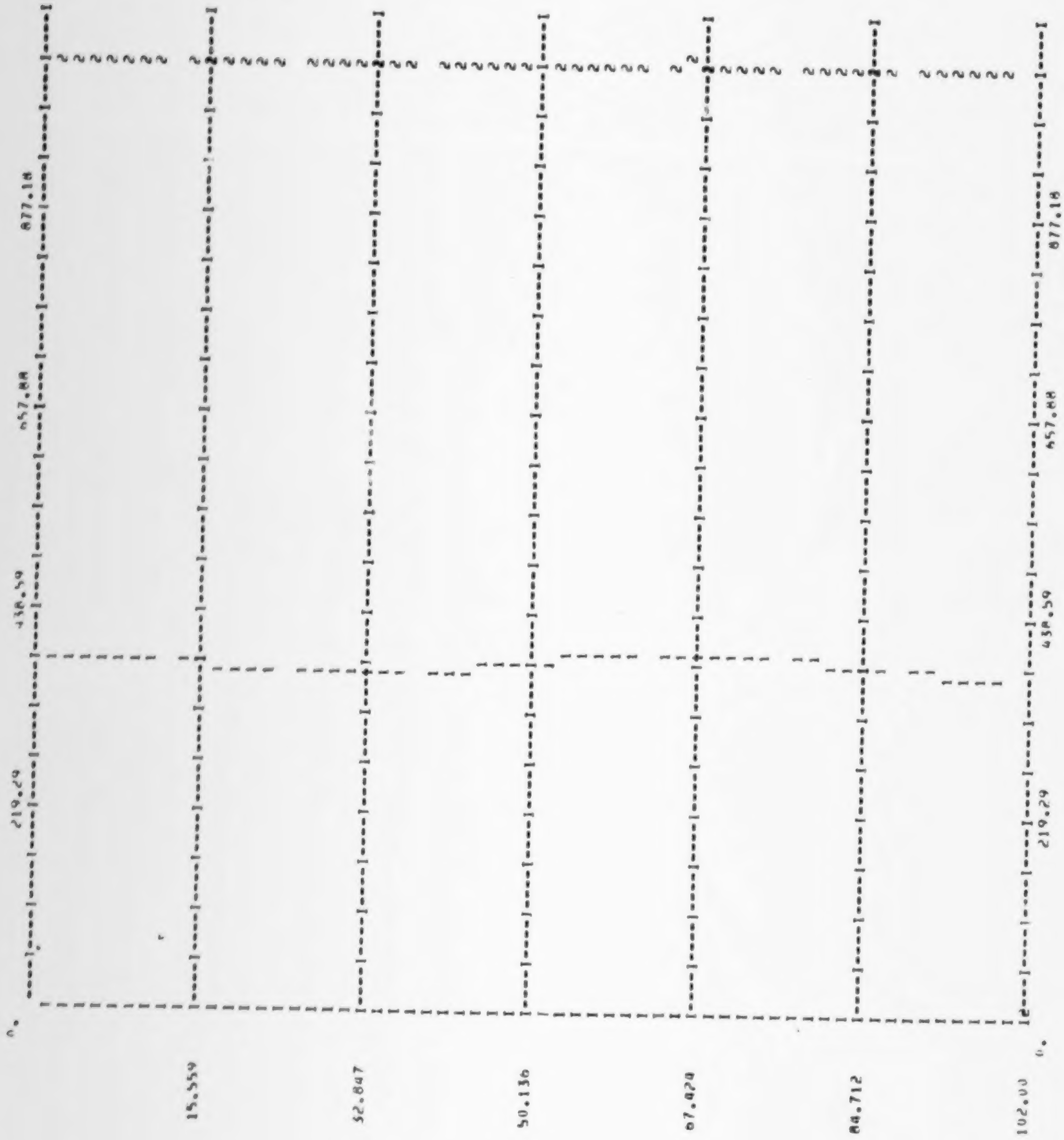
RUN J-S-3 Fluid part of waste

```
                          GRAPH OF    CON:   VS Y AT TIMES
1555.2533             11555.310             -1.0000000          -1.0000000

      RANGE OF    Y    PLOTTED         0.                        102.00000
      RANGE OF   CON   PLOTTED         0.                        51.557937
```



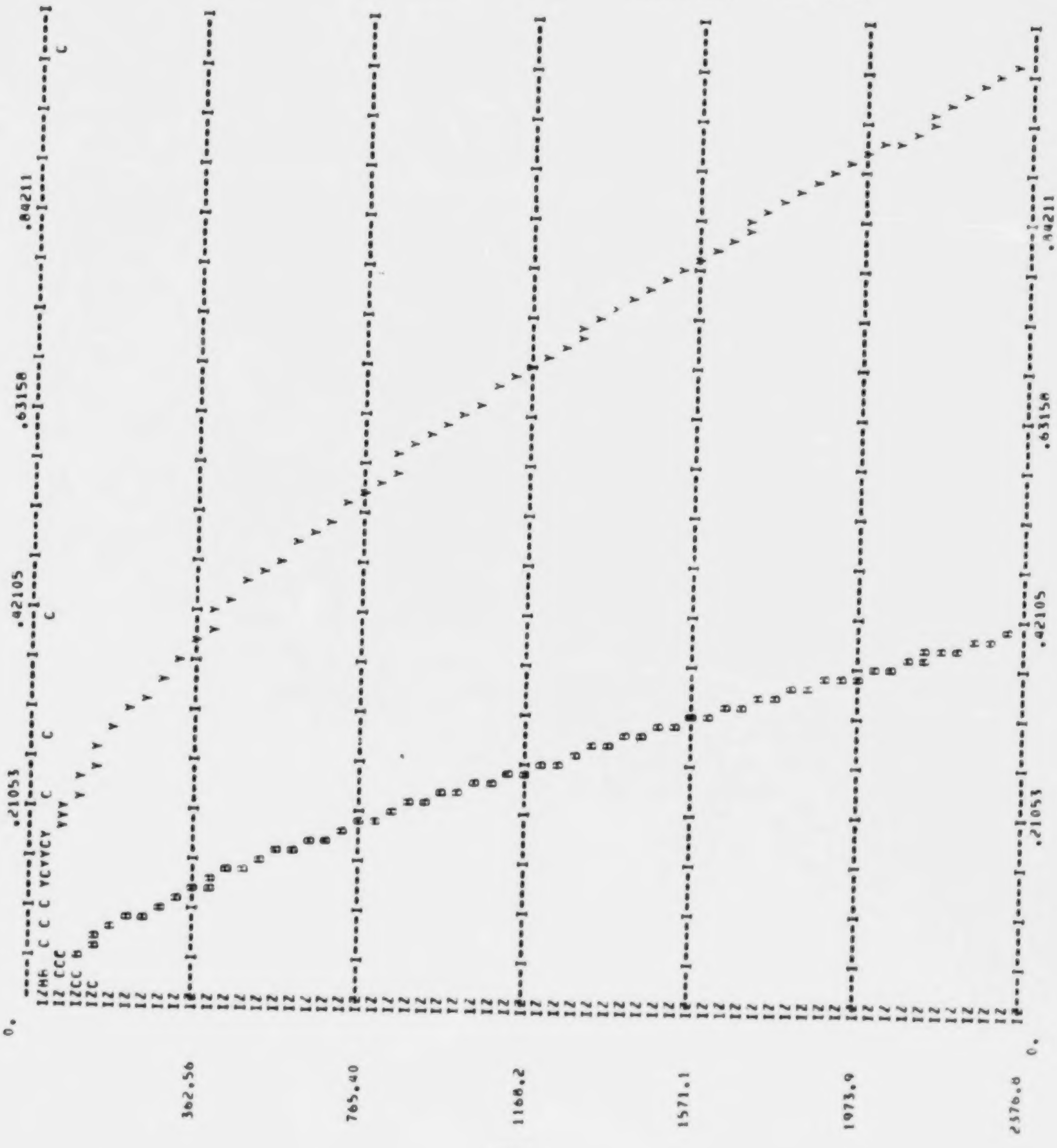
RUN J-S-3 Fluid part of waste

```
                    GRAPH OF   SIZE  VS Y AT TIMES
1553.2533          11533.510          -1.0000000          -1.0000000

   RANGE OF     Y    PLOTTED        0.                   102.00000
   RANGE OF   SIZE   PLOTTED        0.                   1041.6481
```



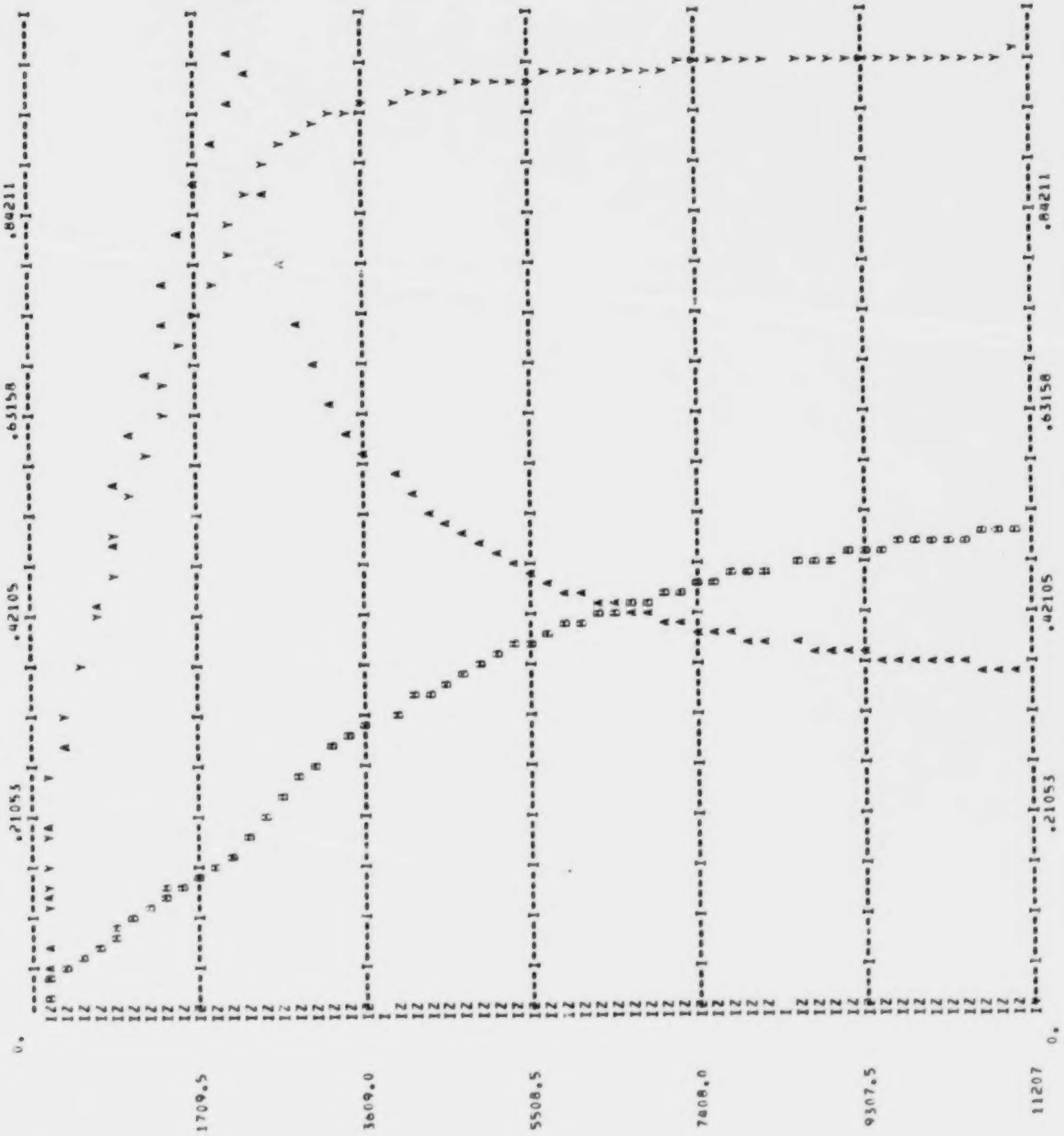
RUN J-S-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          2376.8

                         DEPENDENT VARIABLES

SYMBOL                Y              B              C              Z
MAX PLOTTED       79.307         24.791         .85000          0.
MIN PLOTTED       0.             0.             0.              0.
REMARKS           VERT. DIST.    RADIUS         FLUID CONC.     HOR. DIST.
```

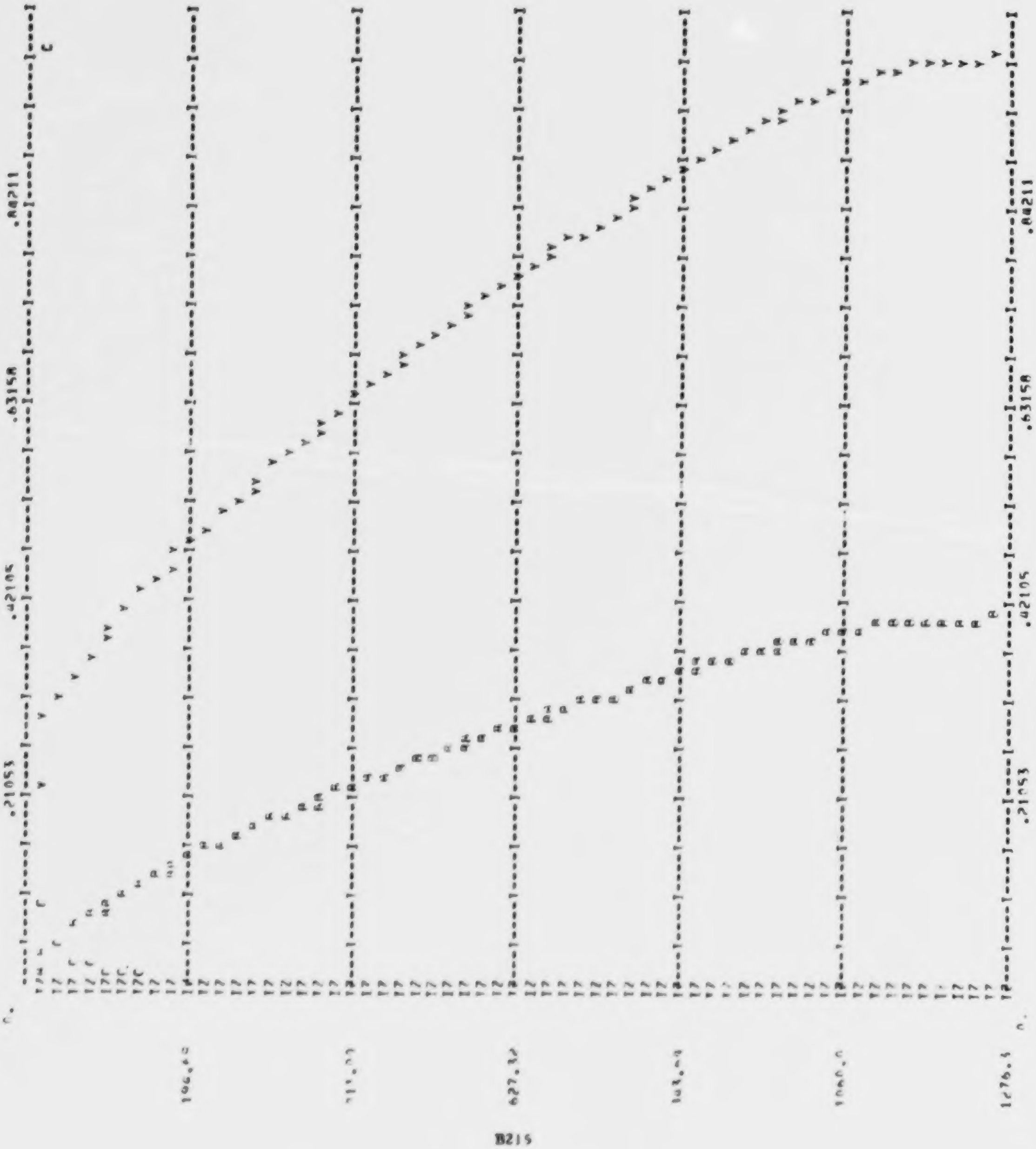


RUN J-S-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          11207

                        DEPENDENT VARIABLES

SYMBOL              A              B              Z              Y
MAX PLOTTED     24.012         72.315         0.             93.086
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```

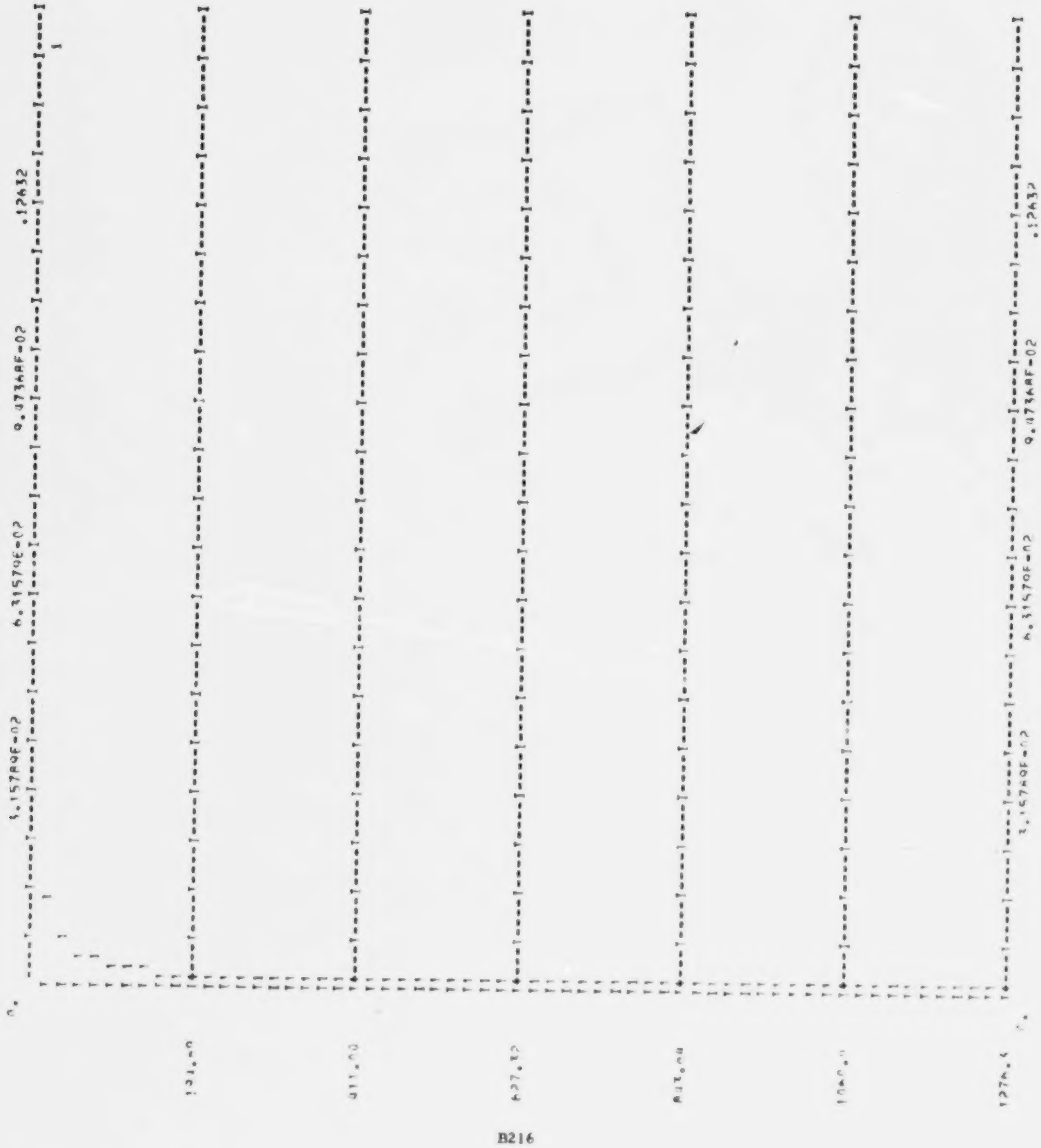


```
                         RUN J-S-5
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1276.3

                  DEPENDENT VARIABLES

SYMBOL              Y              R              C            Z
MAX PLOTTED      95.863         13.423         .85000        0.
MIN PLOTTED      0.             0.             0.            0.
REMARKS          VERT. DIST.     RADIUS        FLUID CONC.   HOR. DIST.
```



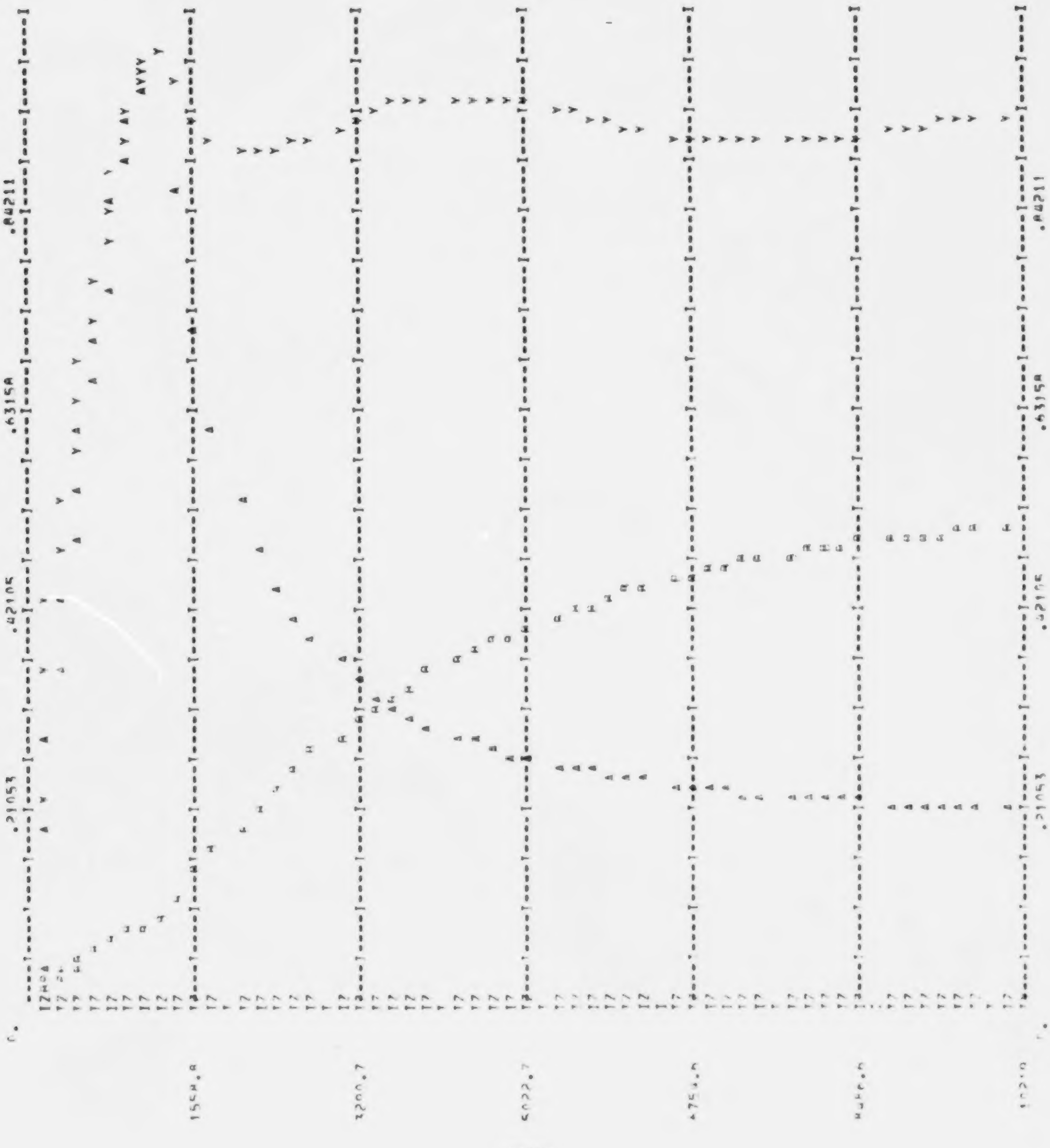
RUN J-S-5

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                           0.              1276.2730
RANGE OF CONCENTRATIONS PLOTTED      0.              .15000000
```



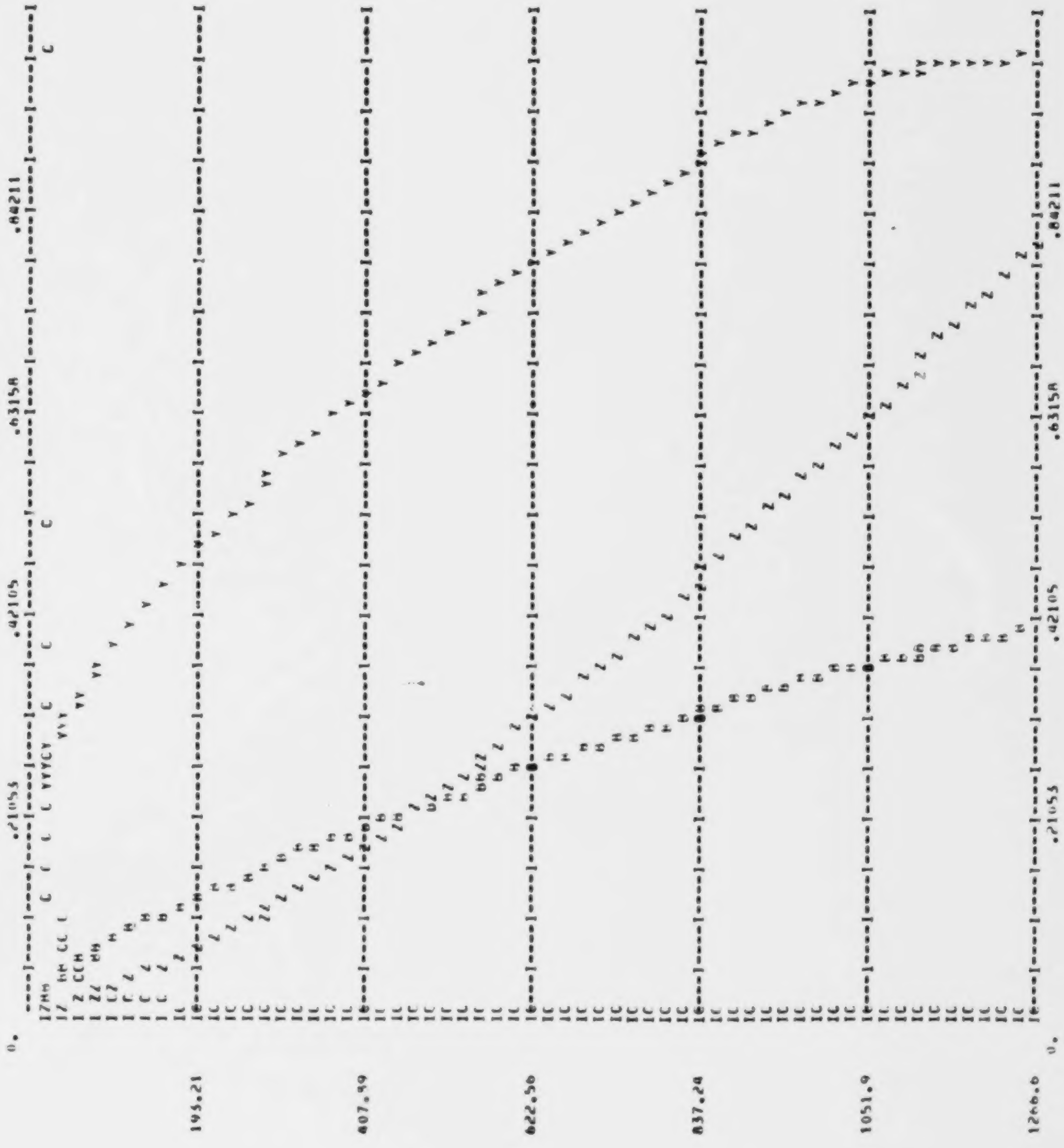
RUN J-S-5

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.              10219

                      DEPENDENT VARIABLES

SYMBOL              A              H              Z              Y
MAX PLOTTED      13.390         79.483         0.             45.829
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```

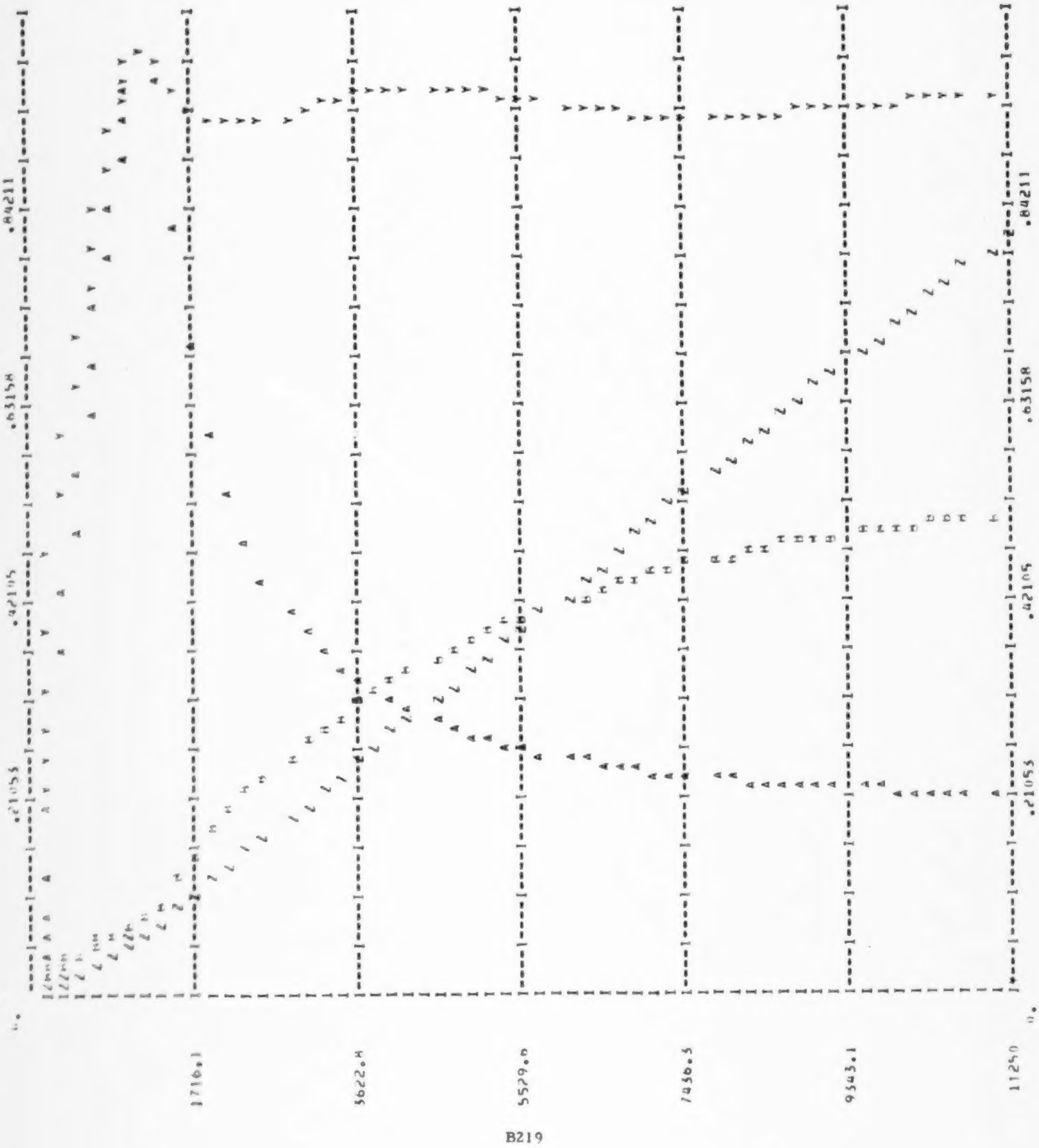


RUN J-S-6

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1266.6

                        DEPENDENT VARIABLES

SYMBOL            Y             R             C             Z
MAX PLOTTED     45.345        14.392        .85000        84.500
MIN PLOTTED     0.            0.            0.            0.
REMARKS         VERT. DIST.   RADIUS        FLUID CONC.   HOR. DIST.
```

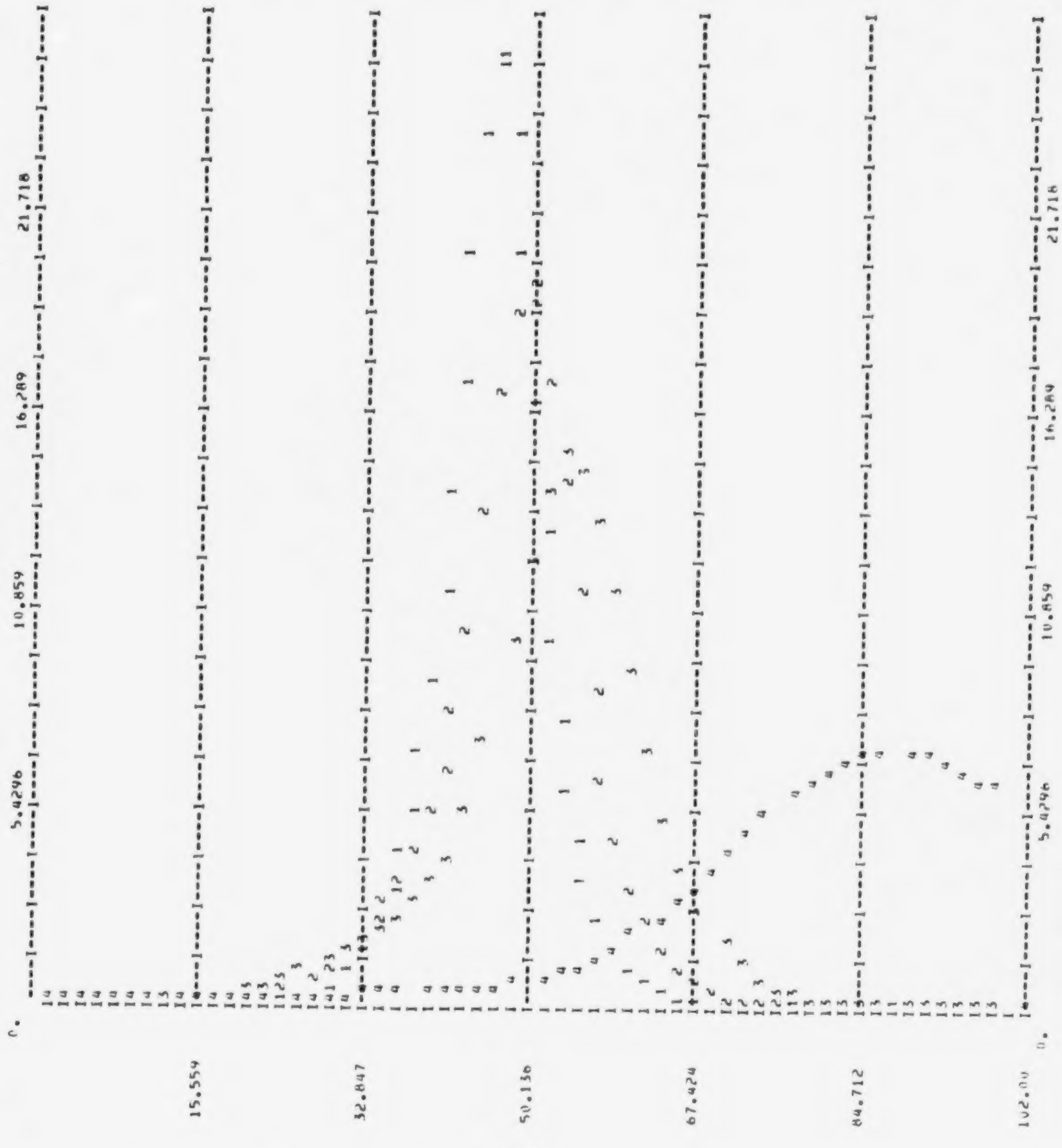


```
                              RUN J-S-6
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            11250

                         DEPENDENT VARIABLES

SYMBOL              A              B              Z             Y
MAX PLOTTED       14.181         94.537         1032.8        45.320
MIN PLOTTED      0.             0.             0.            0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.    VERT. DIST.
```



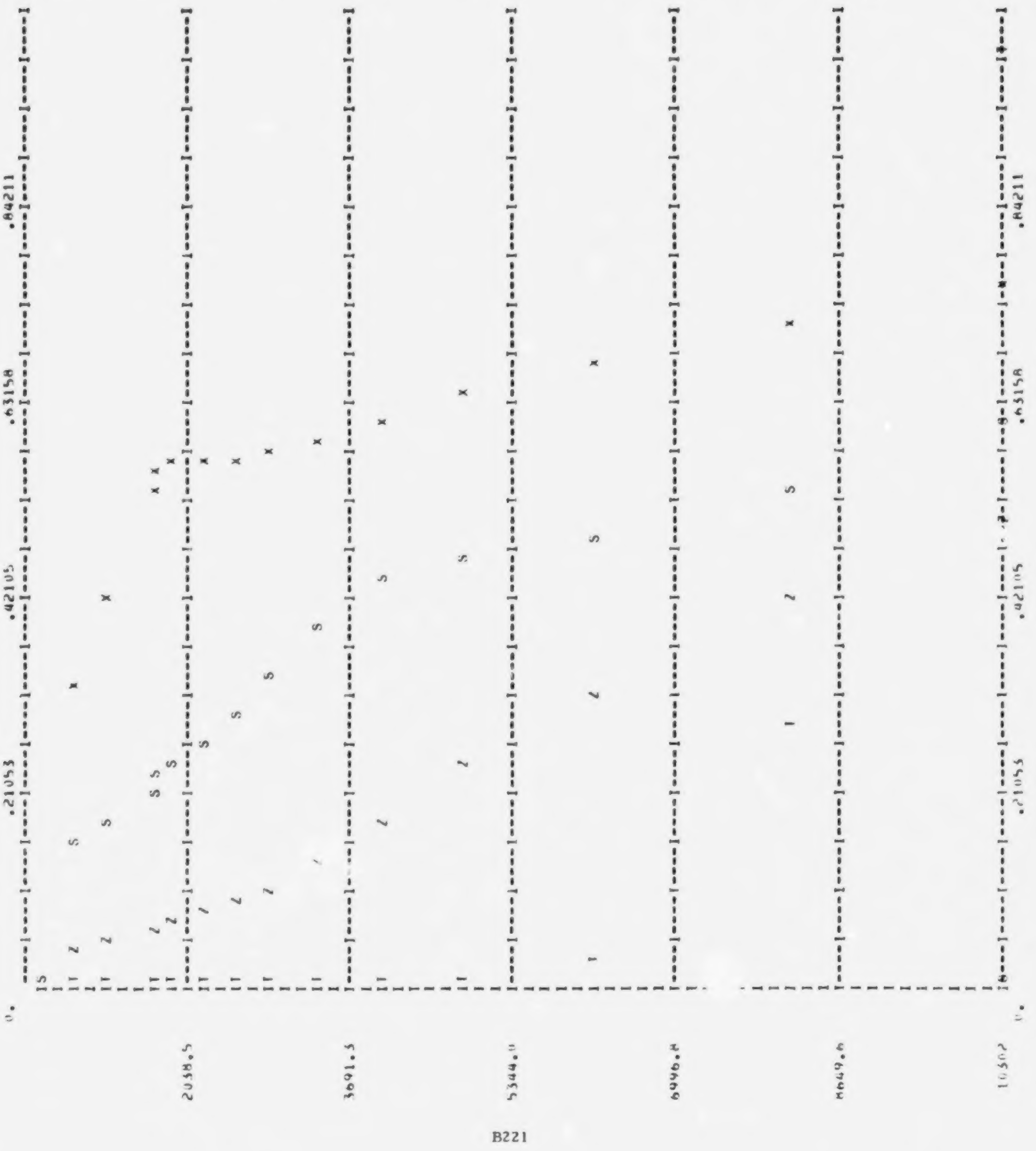
RUN J-S-6

```
                         GRAPH OF    COD    VS Y AT TIMES
        2011.3406             2578.5783            3473.5227            10302.353

              RANGE OF    Y    PLOTTED         0.                        102.00000
              RANGE OF   COD   PLOTTED         0.                        25.790657
```



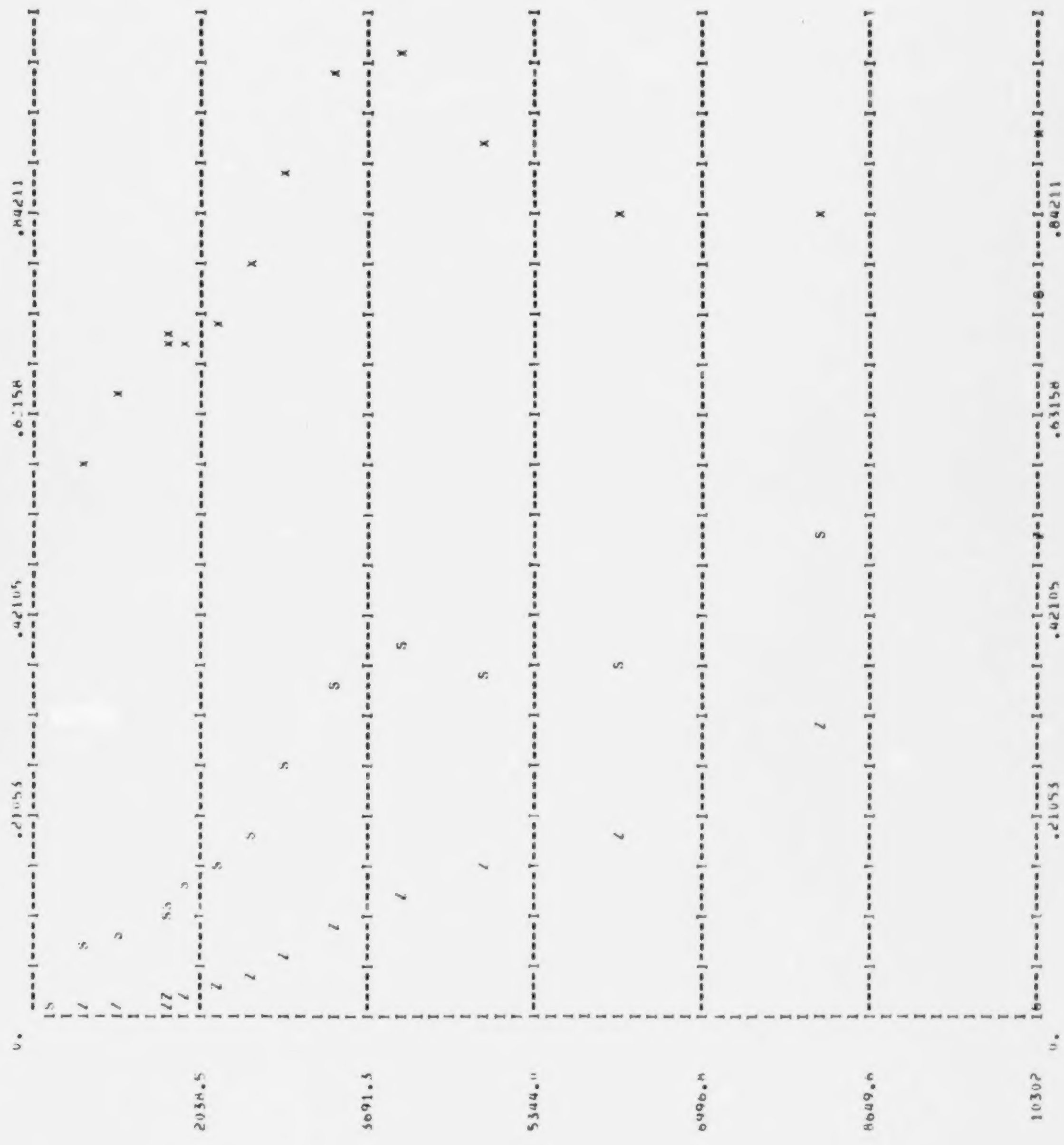
RUN J-S-6

```
PLOT OF TOT HDRY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME
TIME RANGE           550.98731       10302.353
MAXIMUM T,X,Z,S      65.544646       16852.791       4854.7645       2175.[illegible]      *
MINIMUM T,X,Z,S      0.              0.              0.              0.
```



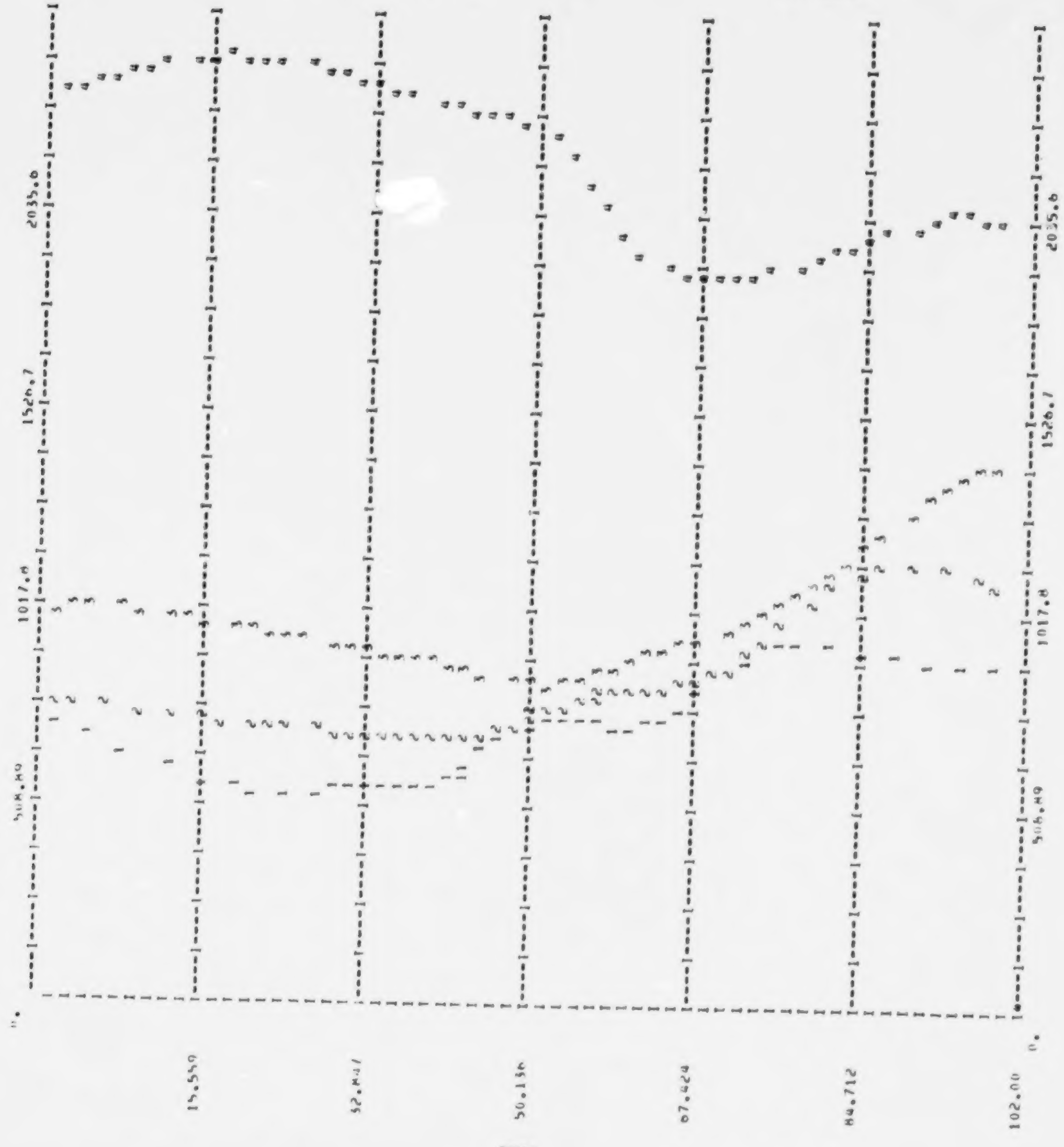
RUN J-S-6

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME

TIME RANGE=           550.96731          10302.353
MAXIMUM X,Z,S         3035245.3          839279.83          973797.74
MINIMUM X,Z,S        0.                 0.                 0.
```



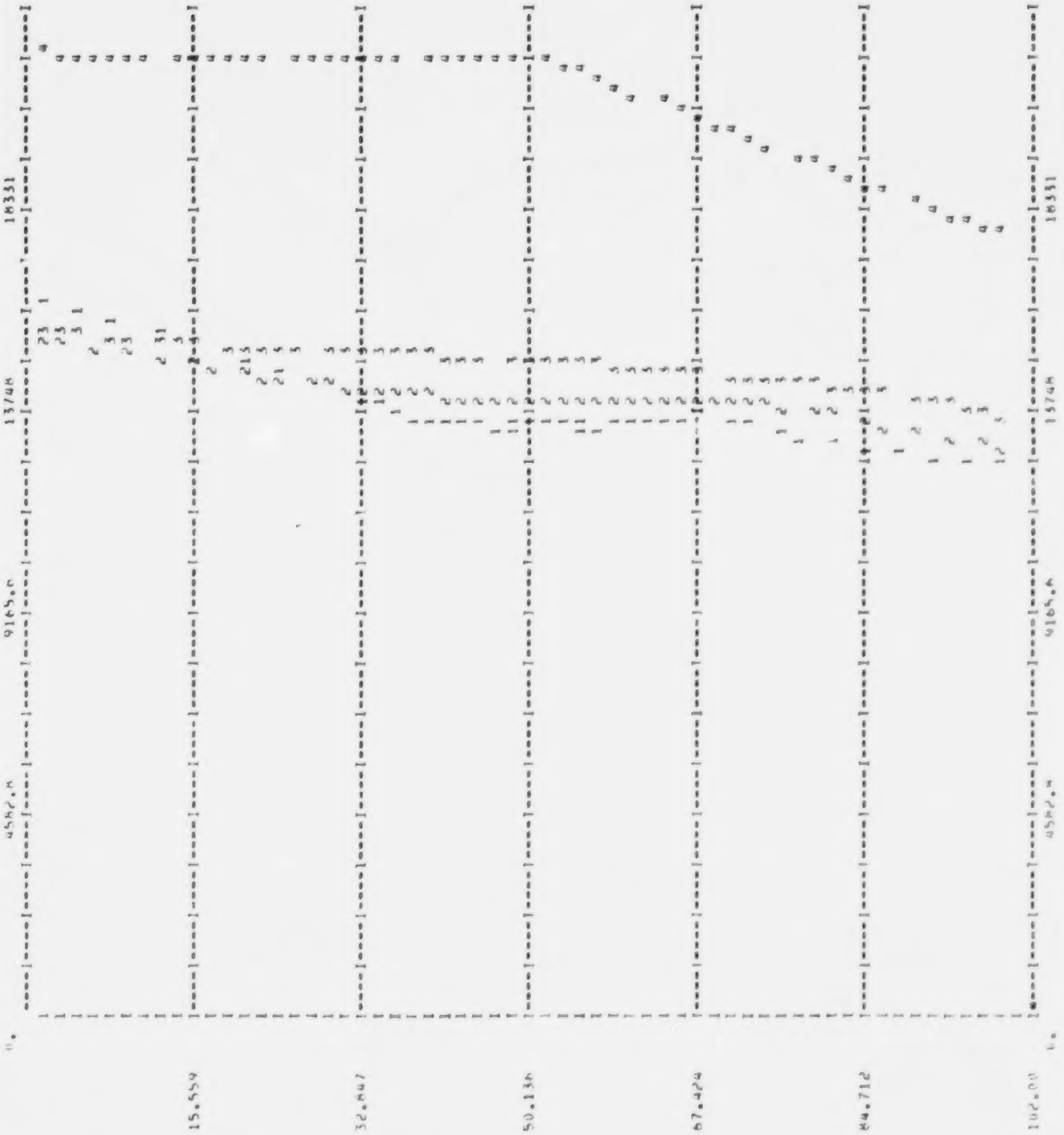
RUN J-S-6

```
                         GRAPH OF   SIZE  VS Y AT TIMES
2011.5406             2578.5783           3473.5227            10302.353
        RANGE OF    Y   PLOTTED         0.                   102.00000
        RANGE OF  SIZE  PLOTTED         0.                   2417.2363
```



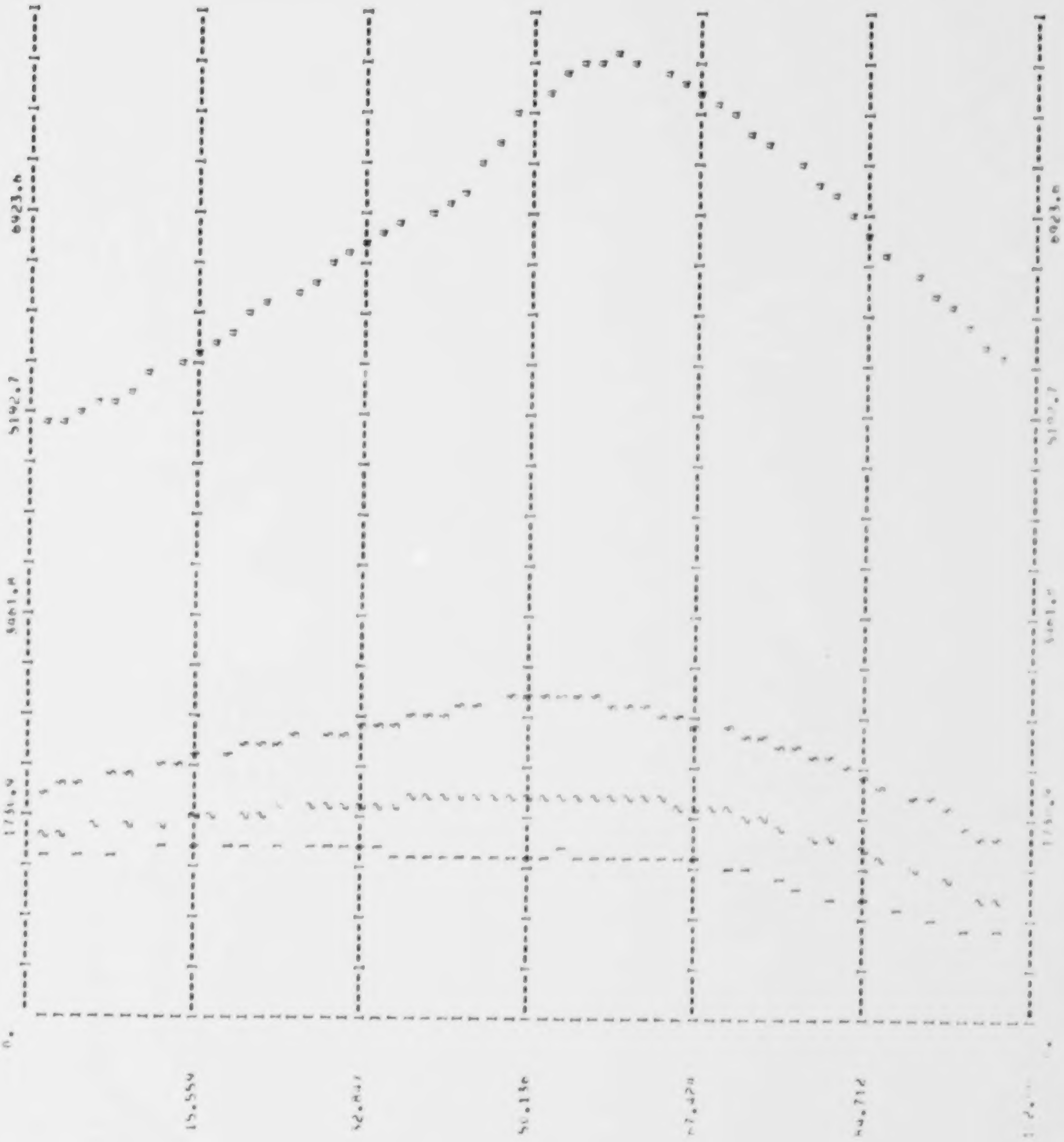
RUN J-S-6

```
                         GRAPH OF    XO   VS Y AT TIMES
    2011.3406           2578.5783         3473.5227           10302.353

         RANGE OF    Y    PLOTTED       0.                    102.00000
         RANGE OF    XO   PLOTTED       0.                    21768.322
```



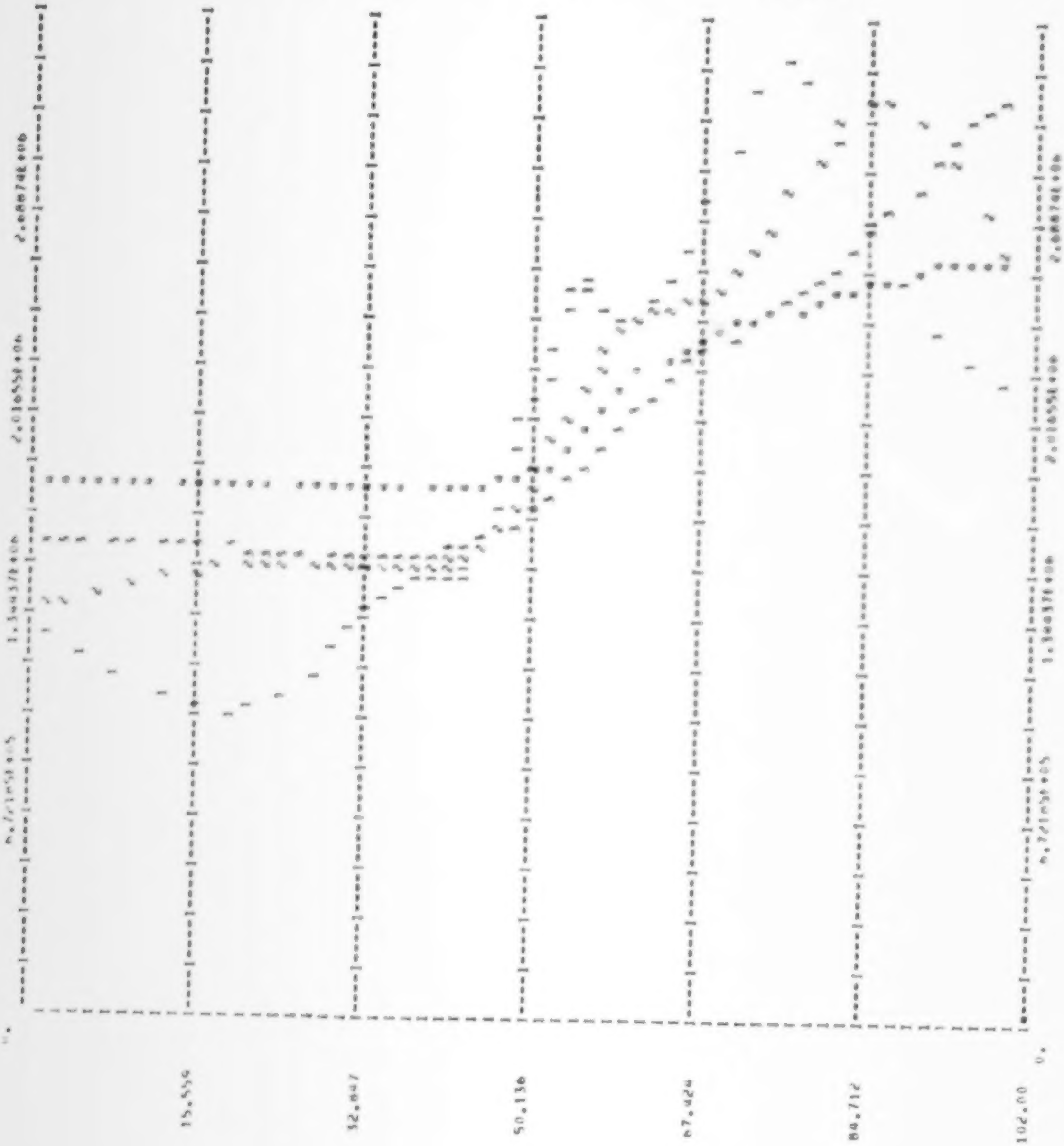
RUN J-S-6

```
                    GRAPH OF    ZG   VS Y AT TIMES
2011.3406          2578.5785          5473.5227          10302.553

        RANGE OF    Y    PLOTTED        0.                 102.00000
        RANGE OF    ZG   PLOTTED        0.                 8221.7902
```



RUN J-S-6

```
                              GRAPH OF SIGMA-X VS Y AT TIMES
2011.3406             2578.5783                    3473.9227                10302.353
     RANGE OF    Y    PLOTTED          0.                              102.00000
     RANGE OF SIGMA-X PLOTTED          0.                              5192877.0
```

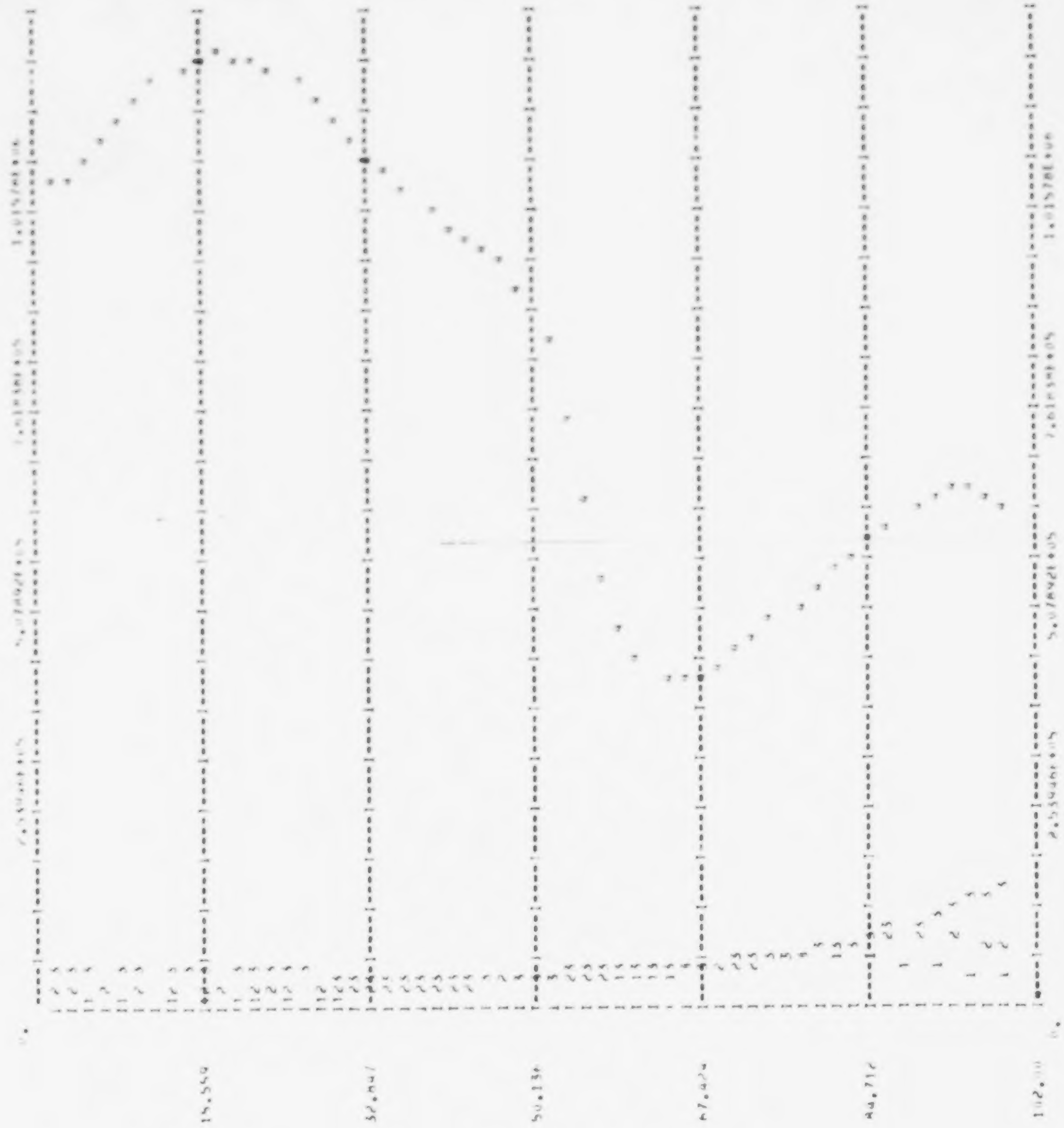


RUN 3-S.6

GRAPH OF SIGMA=Z VS X AT TIMES

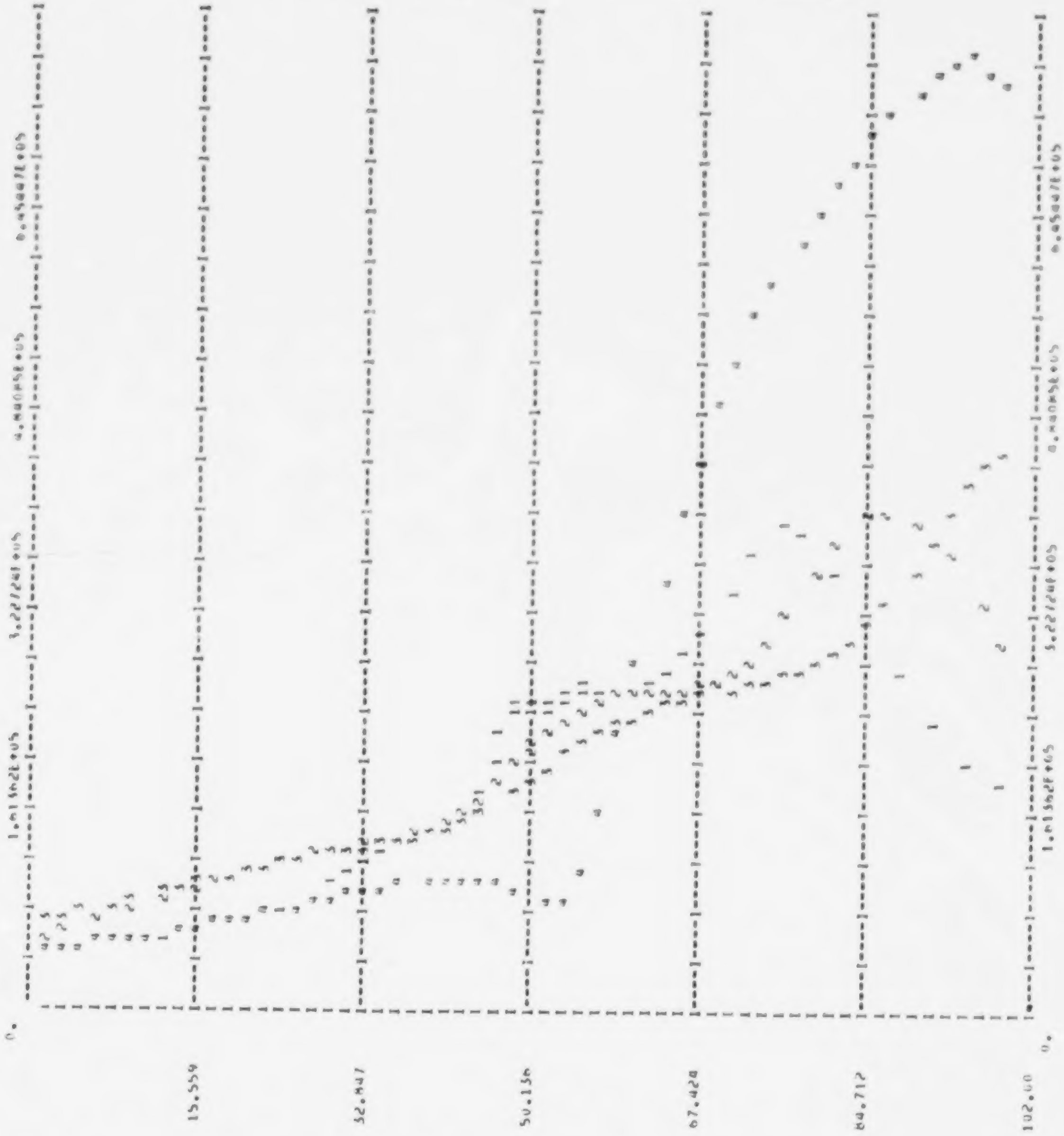
2011.5996 2576.5783 5873.5227 10302.355

RANGE OF X PLOTTED 0. 102.00000
RANGE OF SIGMA=Z PLOTTED 0. 1206286.0

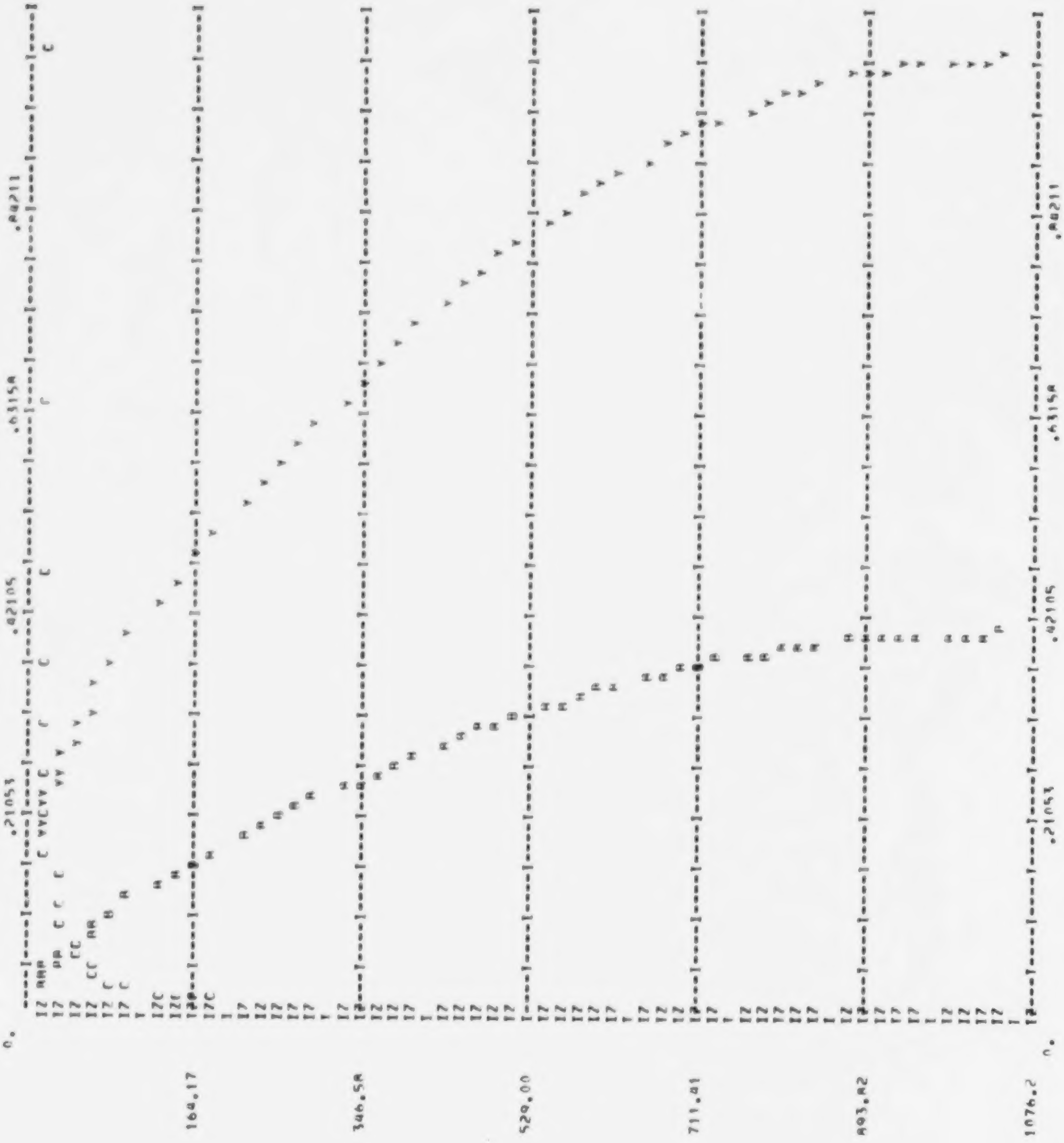


RUN J-S-6

```
                              GRAPH OF SIGMAXZ VS Y AT TIMES
2011.5408                2578.5783              3473.5227             10302.553

     RANGE OF    Y     PLOTTED        0.                        102.00000
     RANGE OF SIGMAXZ PLOTTED        0.                        [illegible]
```

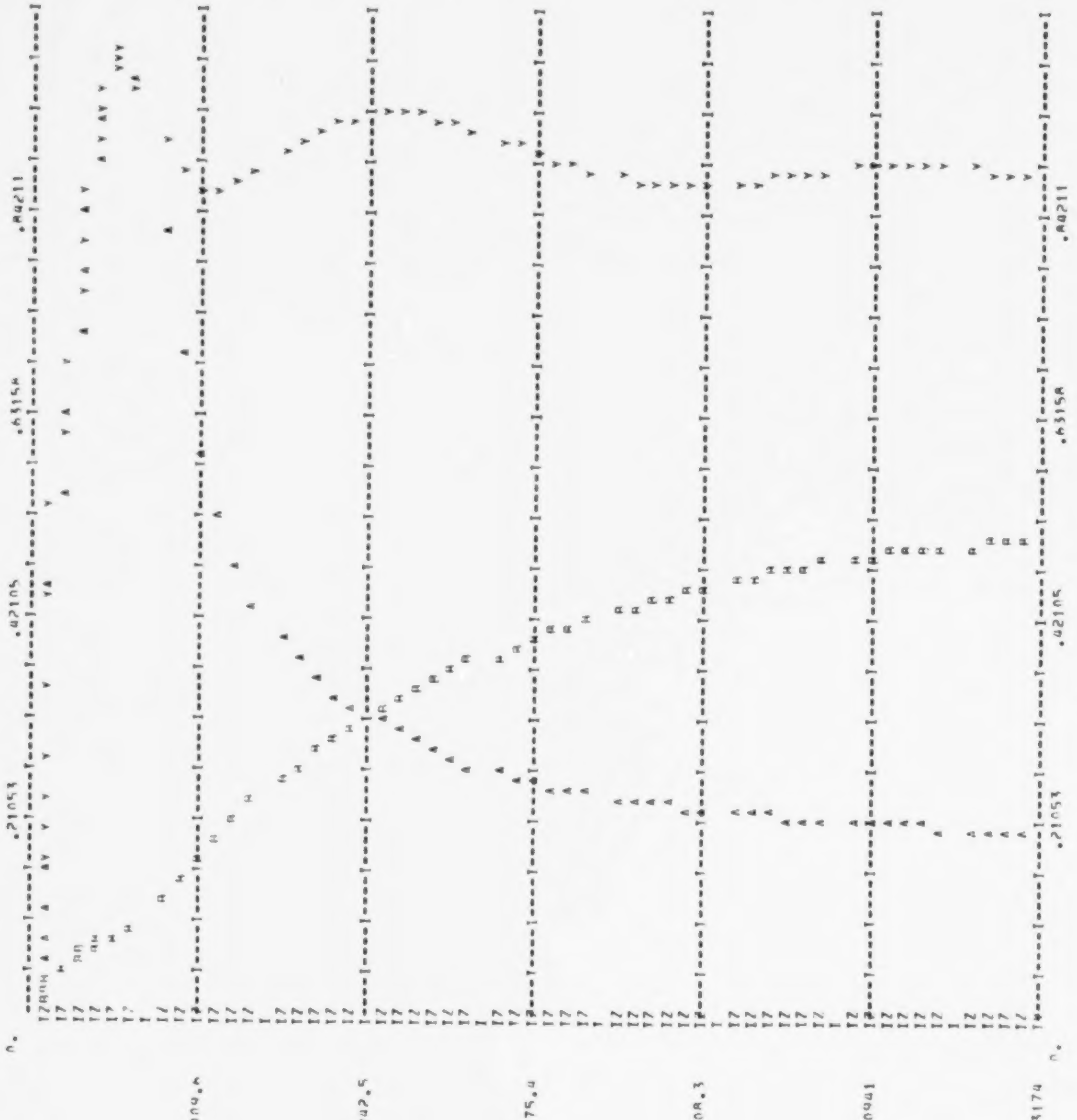


```
                              RUN J-S-7
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1076.2

                         DEPENDENT VARIABLES

SYMBOL              Y              R              C              Z
MAX PLOTTED     60.886         18.688         .85000         0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.     RADIUS        FLUID CONC.     HOR. DIST.
```

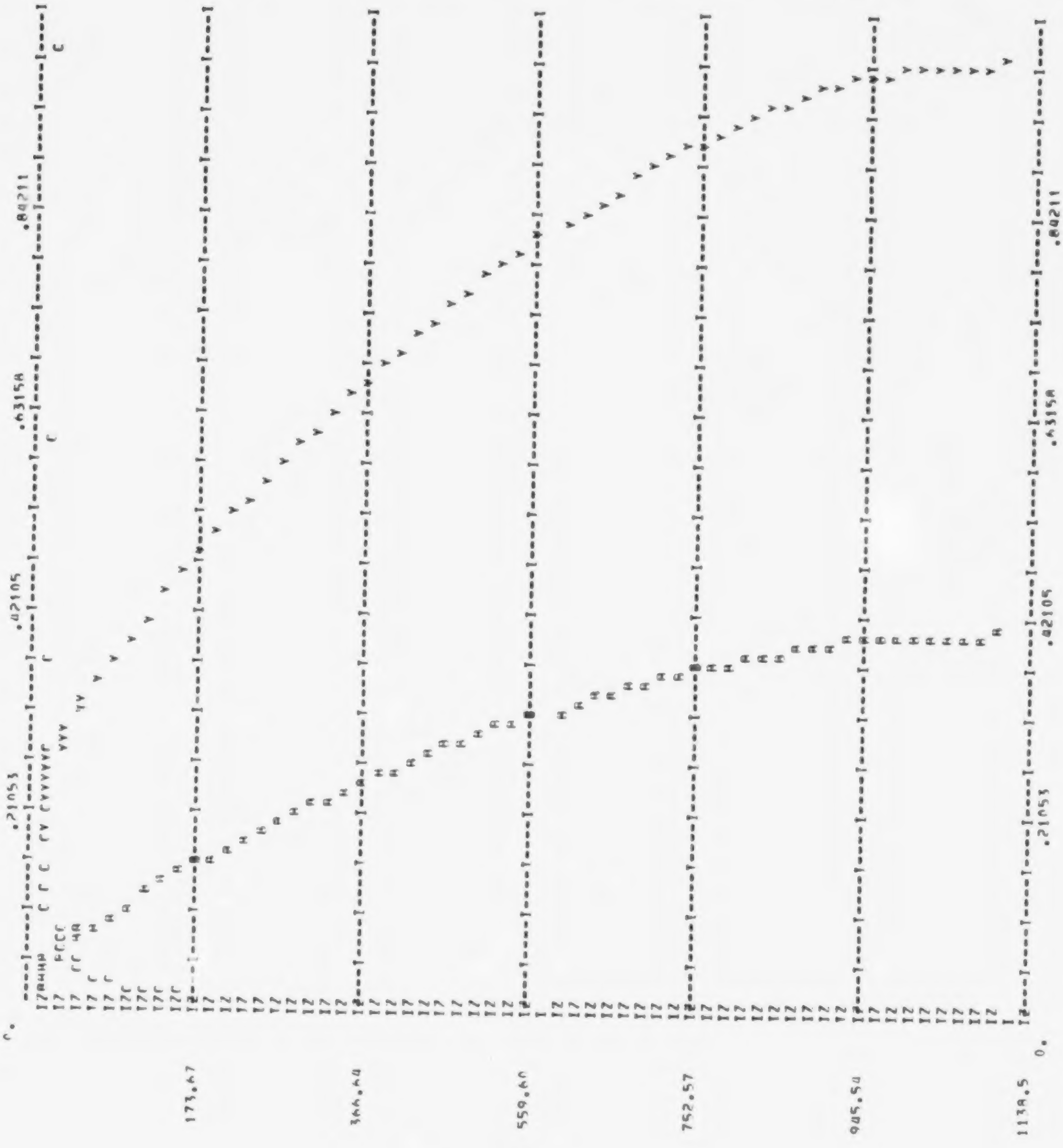


RUN J-S-7

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          13174

                    DEPENDENT VARIABLES

SYMBOL              A               B               Z              Y
MAX PLOTTED      18.689          119.68          0.             60.884
MIN PLOTTED     0.              0.              0.             0.
REMARKS         VERT. SIZE.     HOR. SIZE      HOR. DIST.     VERT. DIST.
```

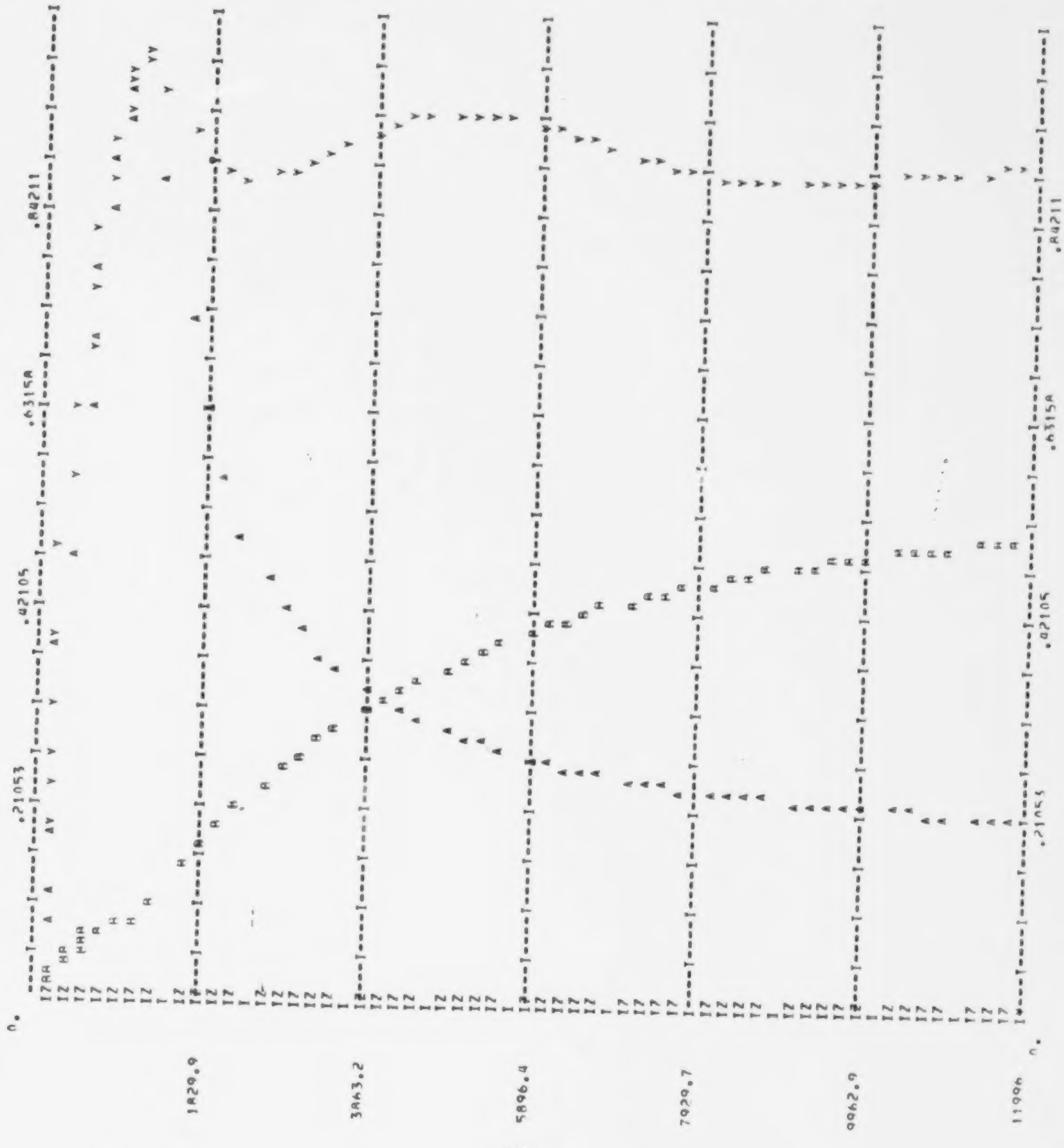


```
                           RUN J-S-8
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1138.5

                     DEPENDENT VARIABLES

SYMBOL             Y              R              C              Z
MAX PLOTTED     58.093         16.153         .85000         0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



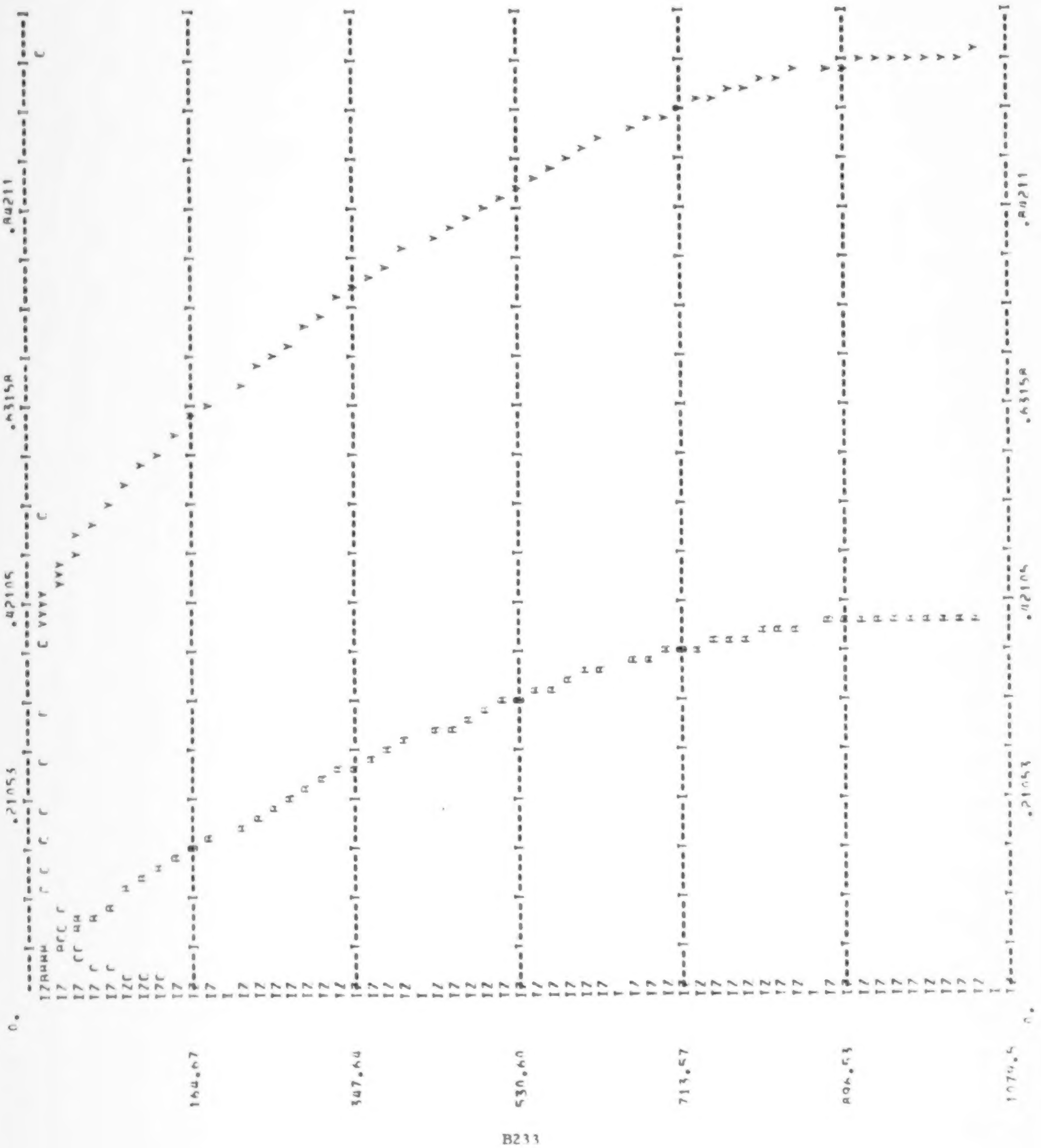
RUN J-S-8

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.           11996

                         DEPENDENT VARIABLES

SYMBOL                A                B             Z              Y
MAX PLOTTED       16.115           98.081        0.             54.022
MIN PLOTTED      0.               0.            0.             0.
REMARKS          VERT. SIZE.     HOR. SIZE     HOR. DIST.     VERT. DIST.
```



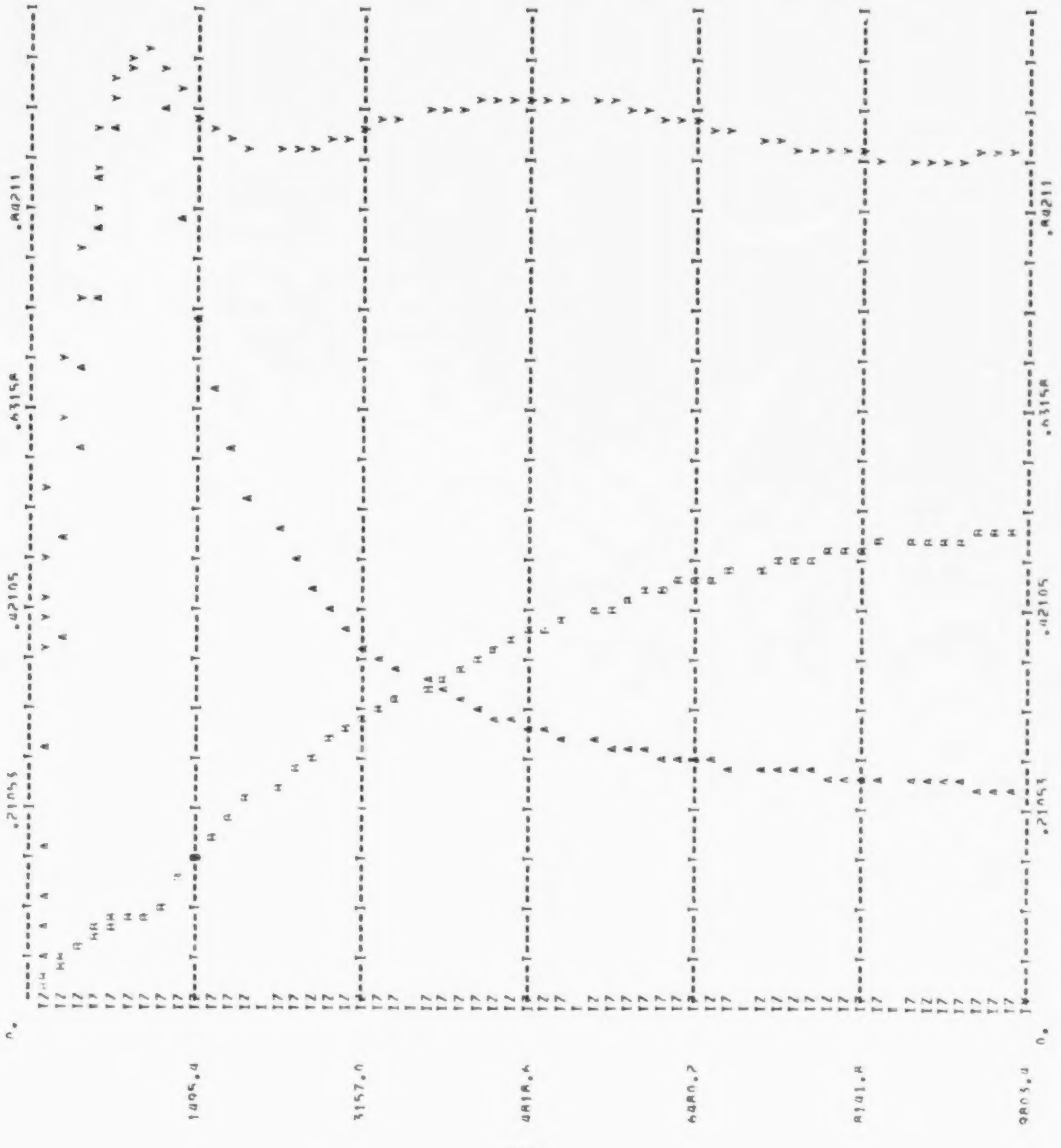
RUN J-S-9

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1079.5

                    DEPENDENT VARIABLES

SYMBOL             Y              R              C              Z
MAX PLOTTED     52.918         11.828         .85000         0.
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



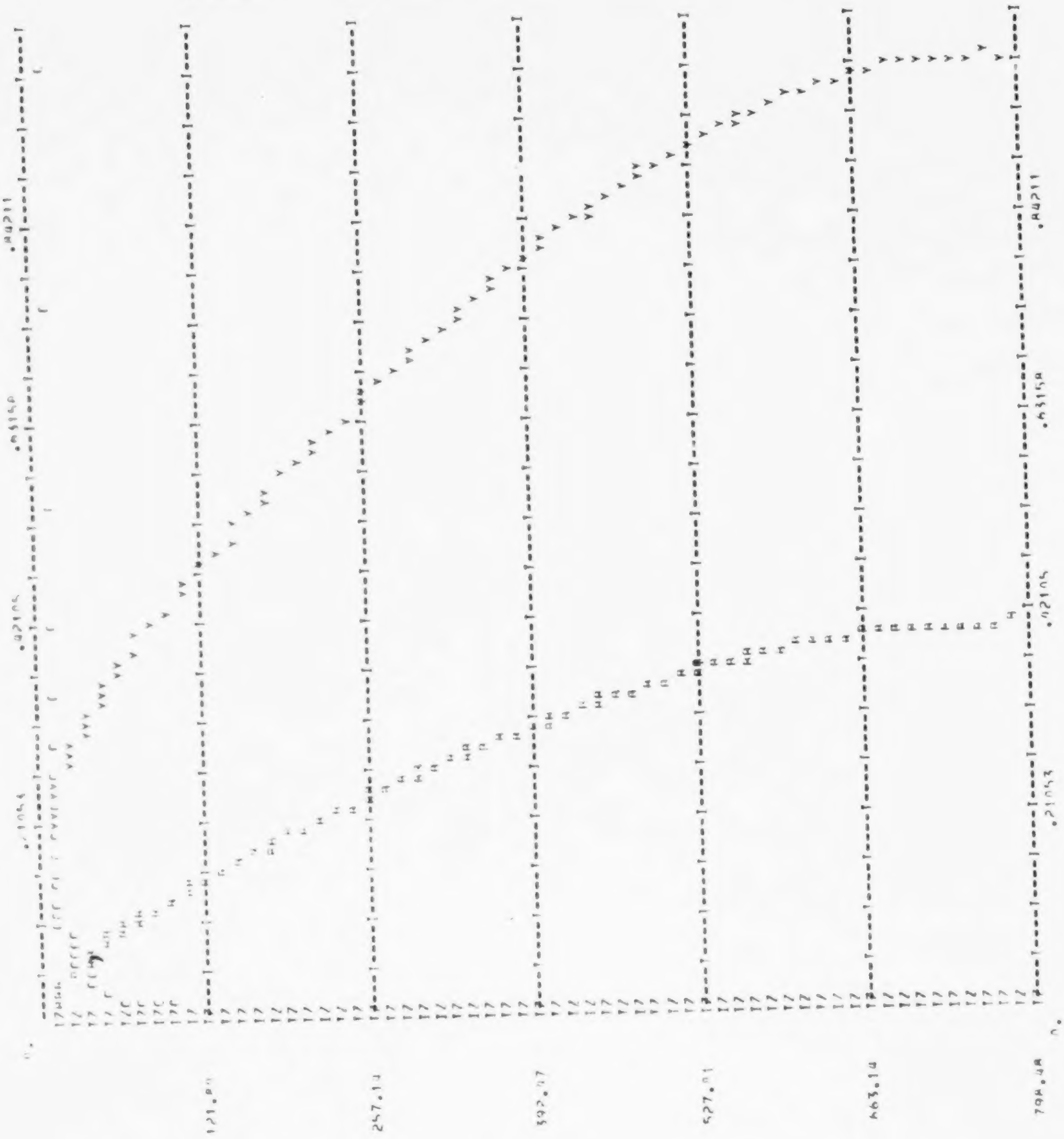
RUN J-S-9

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          9803.4

                    DEPENDENT VARIABLES

SYMBOL              A              B              Z              Y
MAX PLOTTED      11.828         64.628        0.              52.918
MIN PLOTTED      0.             0.            0.              0.
REMARKS          VERT. SIZE.    HOR. SIZE     HOR. DIST.      VERT. DIST.
```



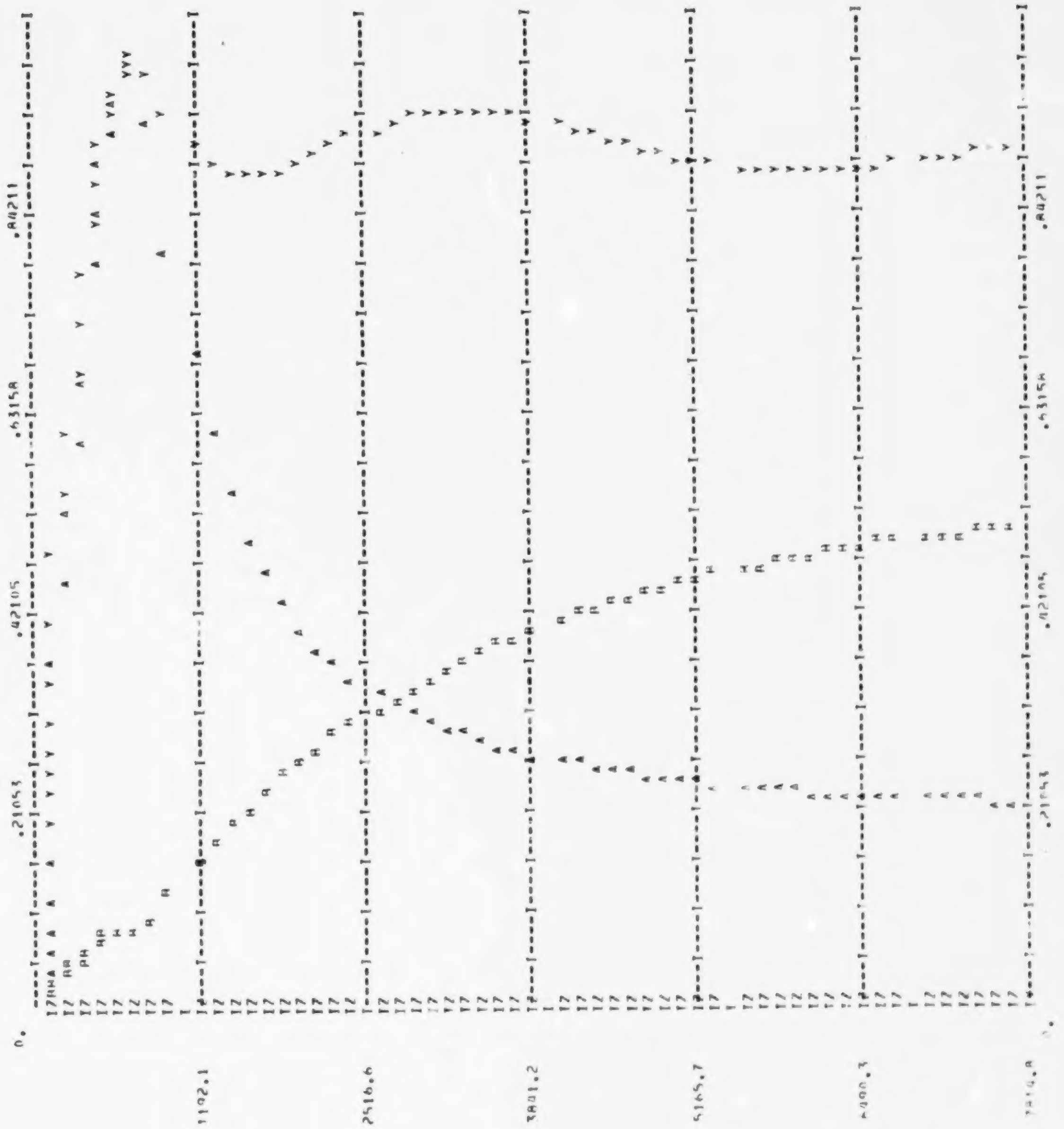
RUN J-S-10

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          798.48

                        DEPENDENT VARIABLES

SYMBOL             Y               R              C             Z
MAX PLOTTED     51.904          15.417         .85000        0.
MIN PLOTTED    0.              0.             0.             0.
REMARKS        VERT. DIST.      RADIUS        FLUID CONC.    HOR. DIST.
```

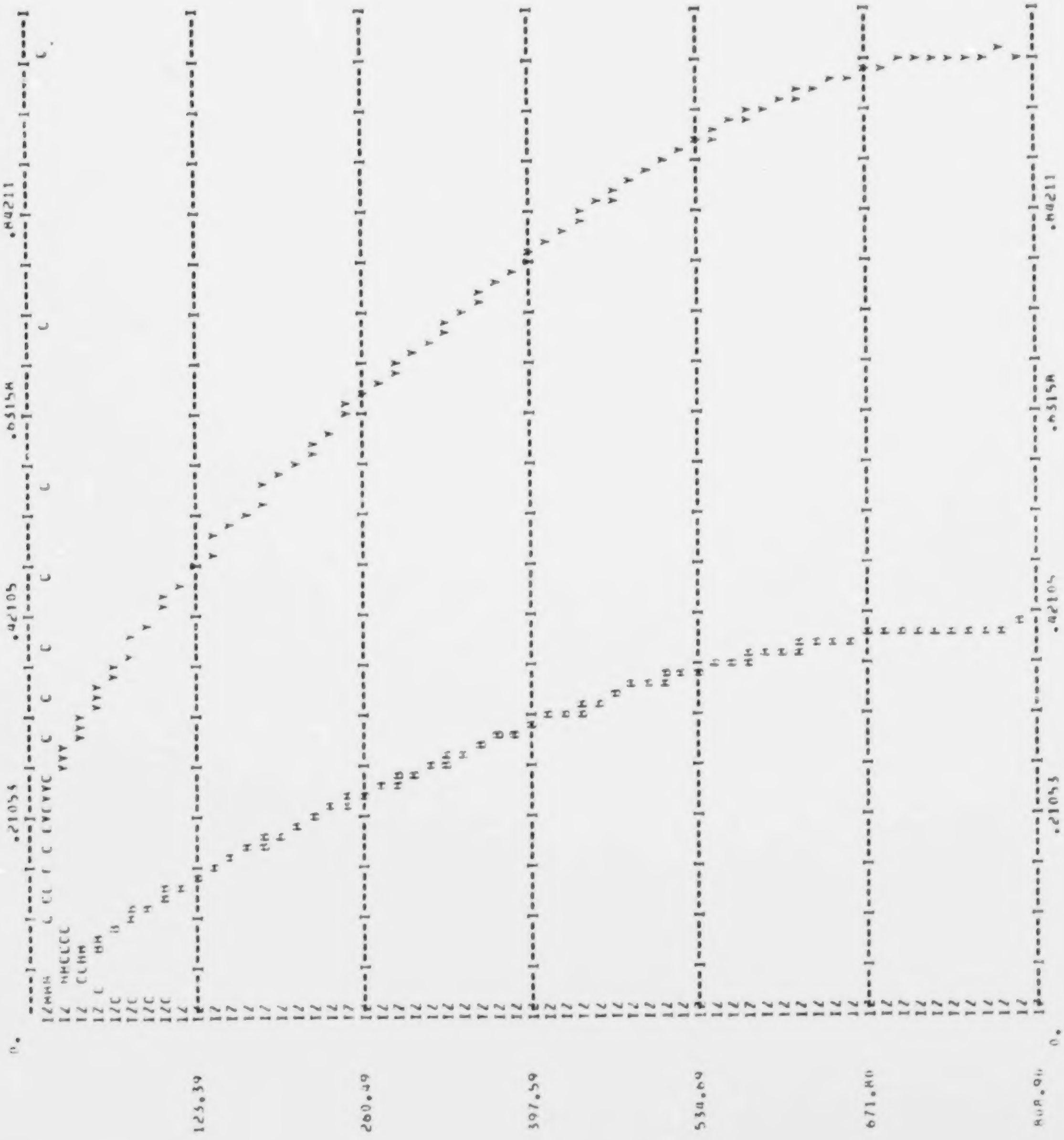


RUN J-S-10

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          7814.8

                        DEPENDENT VARIABLES

SYMBOL             A             B            Z              Y
MAX PLOTTED    15.414        91.858       0.             51.904
MIN PLOTTED    0.            0.           0.             0.
REMARKS        VERT. SIZE.   HOR. SIZE    HOR. DIST.   VERT. DIST.
```

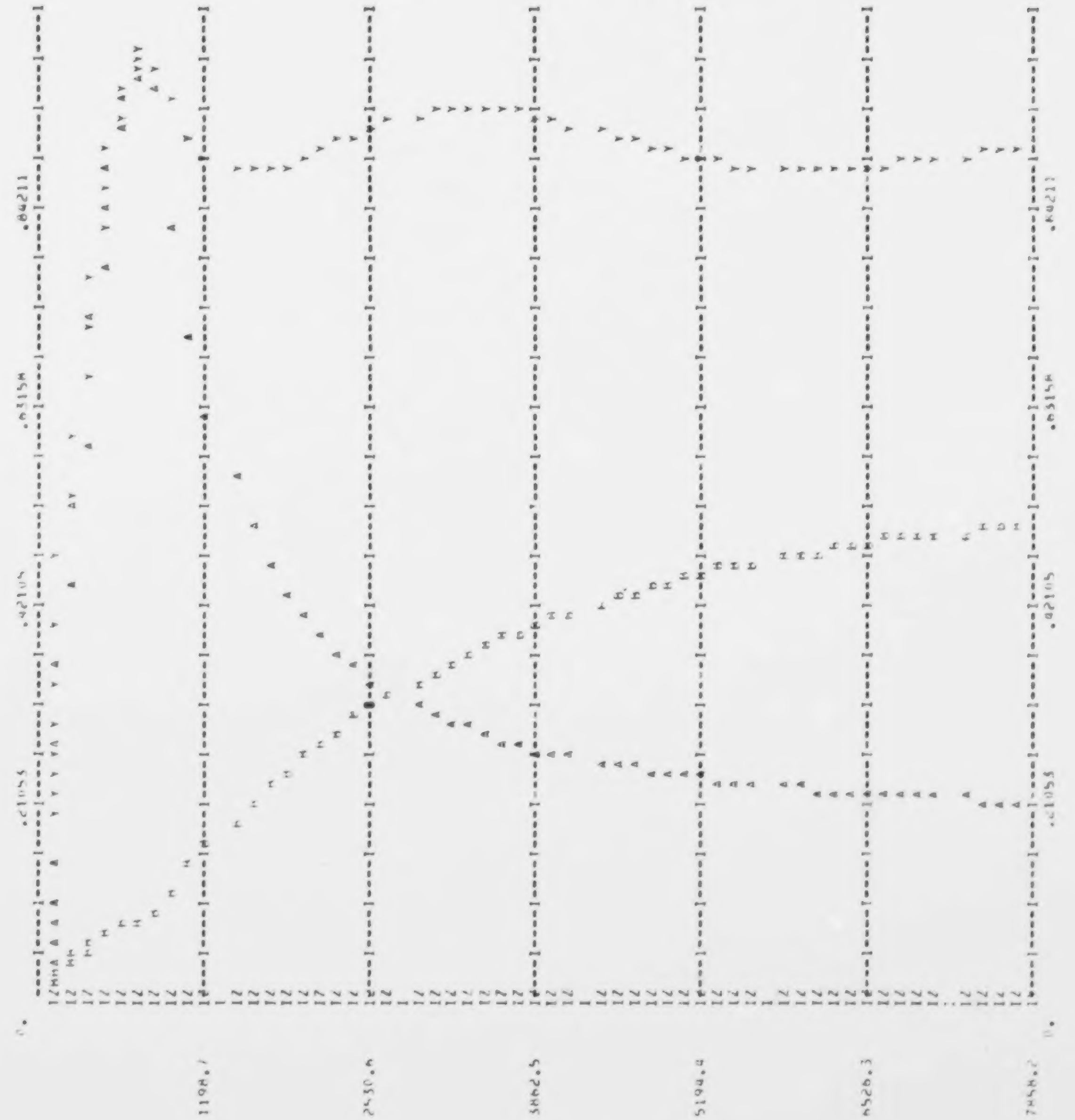


```
                              RUN J-S-11
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          808.90

                         DEPENDENT VARIABLES

SYMBOL              Y              B              C              Z
MAX PLOTTED       51.757         15.559        .85000          0.
MIN PLOTTED       0.             0.            0.              0.
REMARKS           VERT. DIST.    RADIUS        FLUID CONC.     HOR. DIST.
```



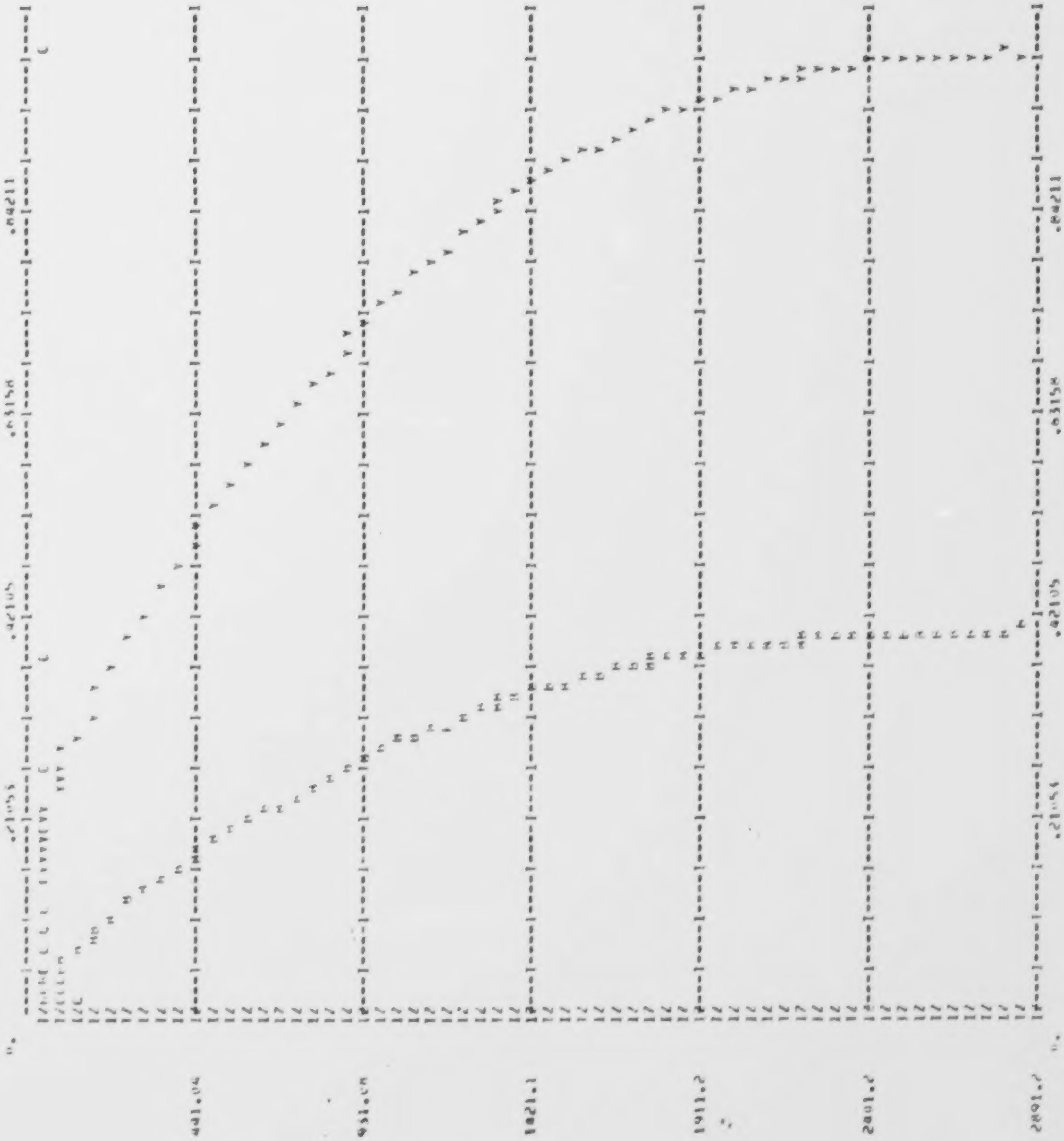
RUN J-S-11

```
INDEPENDENT VARIABLE IS HOR,DIST. OVER RANGE      0.           7858.2

                    DEPENDENT VARIABLES

SYMBOL             A              H              Z              Y
MAX PLOTTED     15.550         93.017         0.             51.747
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```



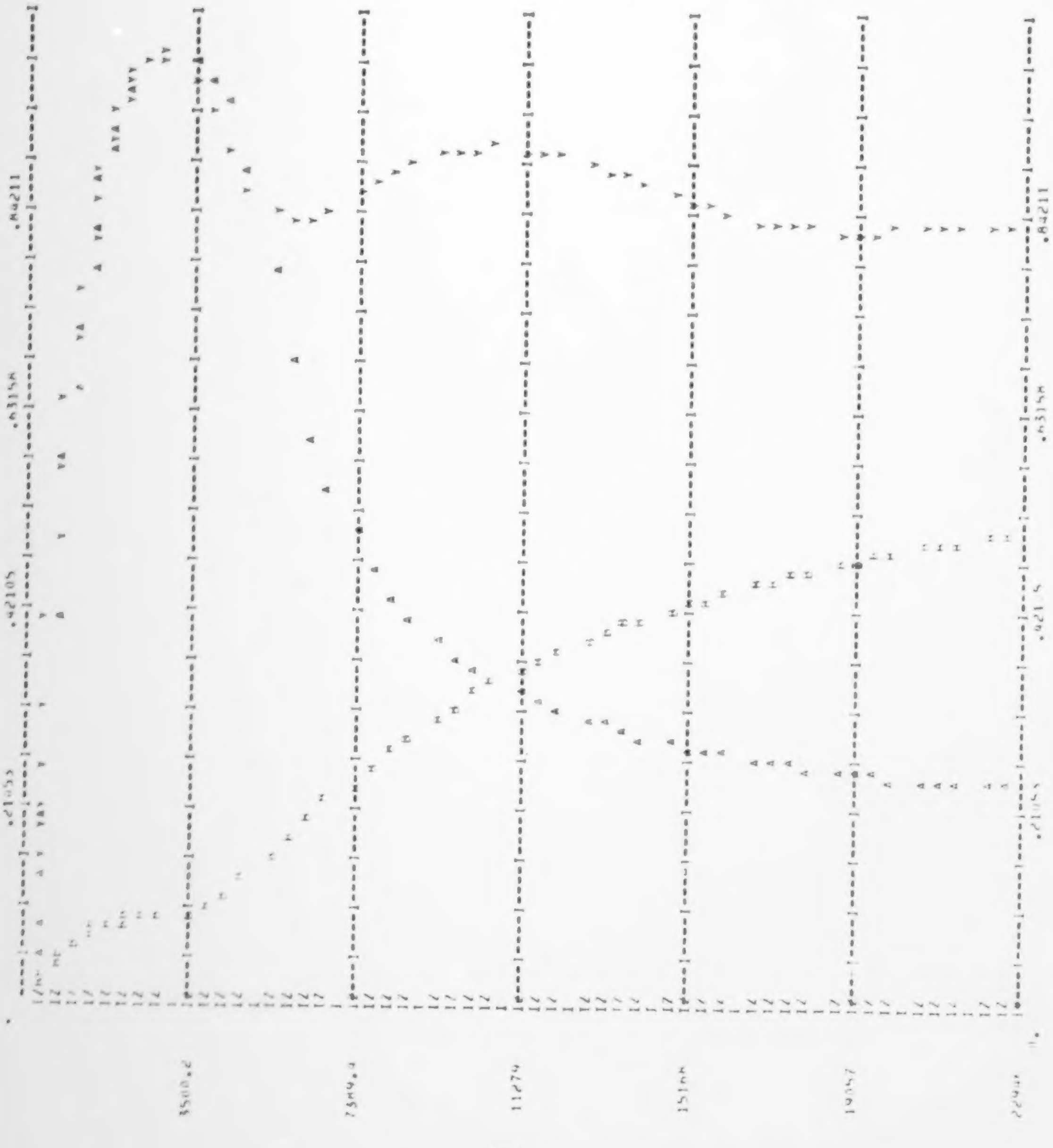
RUN J-S-12

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          2891.2

                    DEPENDENT VARIABLES

SYMBOL              Y              R              C              Z
MAX PLOTTED      66.487         20.238         .85000         0.
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. DIST.    RADIUS         FLUID CONC.    HOR. DIST.
```



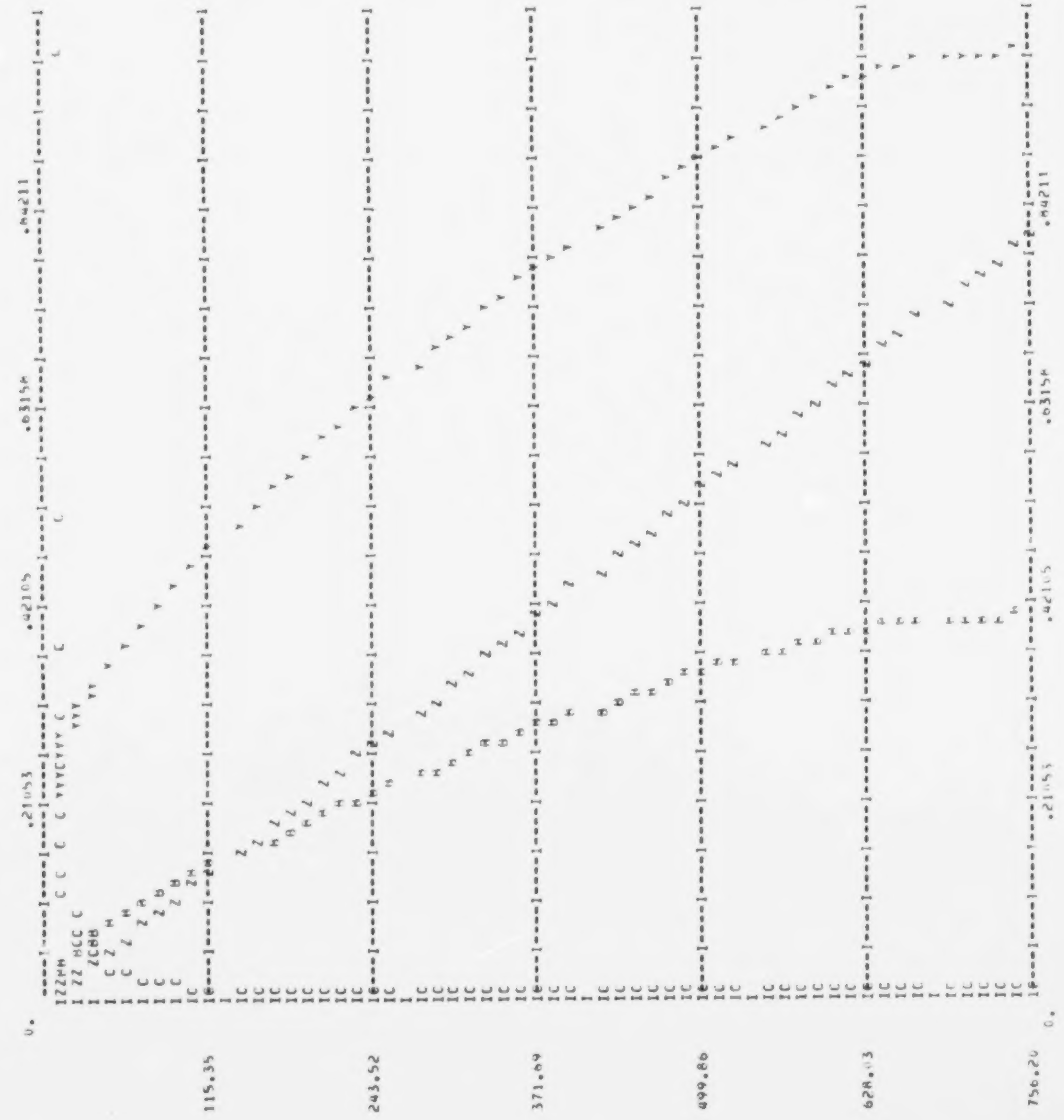
RUN J-S-12

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.           22946

                        DEPENDENT VARIABLES

SYMBOL              A               H             Z              Y
MAX PLOTTED     20.227          118.71        0.             66.461
MIN PLOTTED     0.              0.            0.             0.
REMARKS         VERT. SIZE.     HOR. SIZE     HOR. DIST.     VERT. DIST.
```



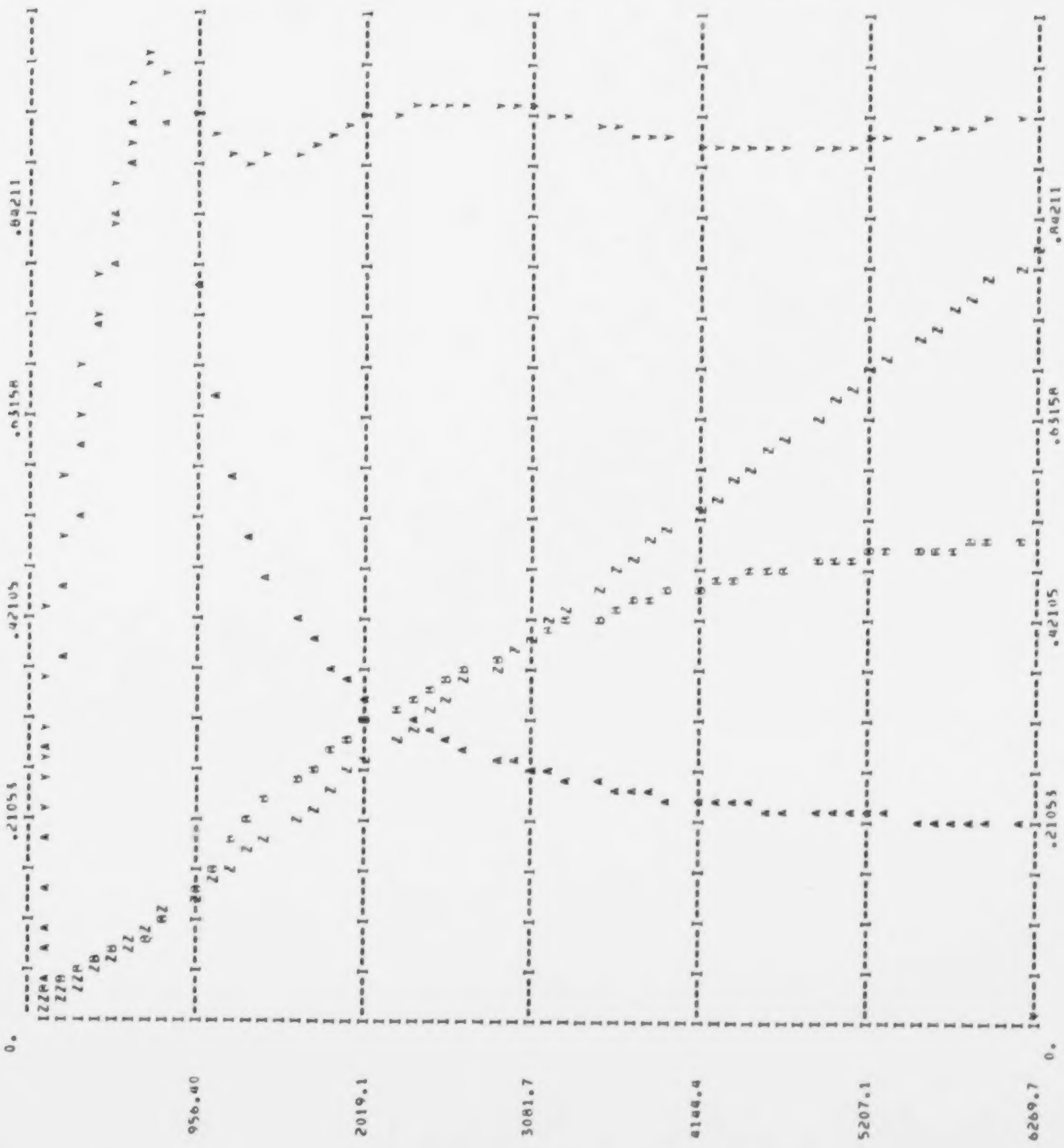
RUN J-F-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          756.20

                          DEPENDENT VARIABLES

SYMBOL              Y             B            C            Z
MAX PLOTTED     48.512       13.115       1.00000       756.20
MIN PLOTTED     0.            0.           0.            0.
REMARKS         VERT. DIST.   RADIUS       FLUID CONC.   HOR. DIST.
```



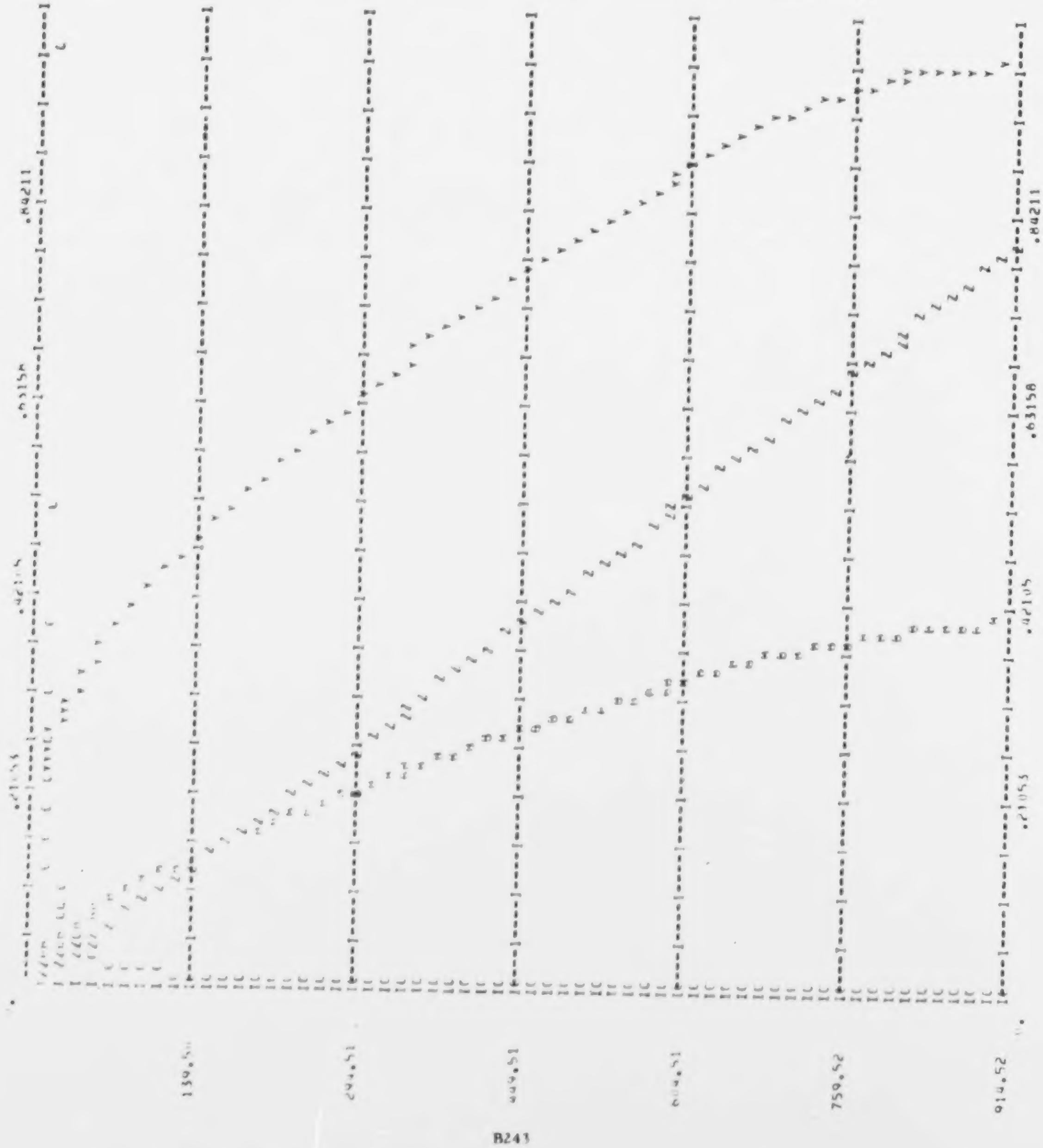
RUN J-F-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.           6269.7

                         DEPENDENT VARIABLES

SYMBOL              A            B             Z             Y
MAX PLOTTED      13.111       77.342        6269.7        46.506
MIN PLOTTED      0.           0.            0.            0.
REMARKS          VERT. SIZE.   HOR. SIZE     HOR. DIST.    VERT. DIST.
```



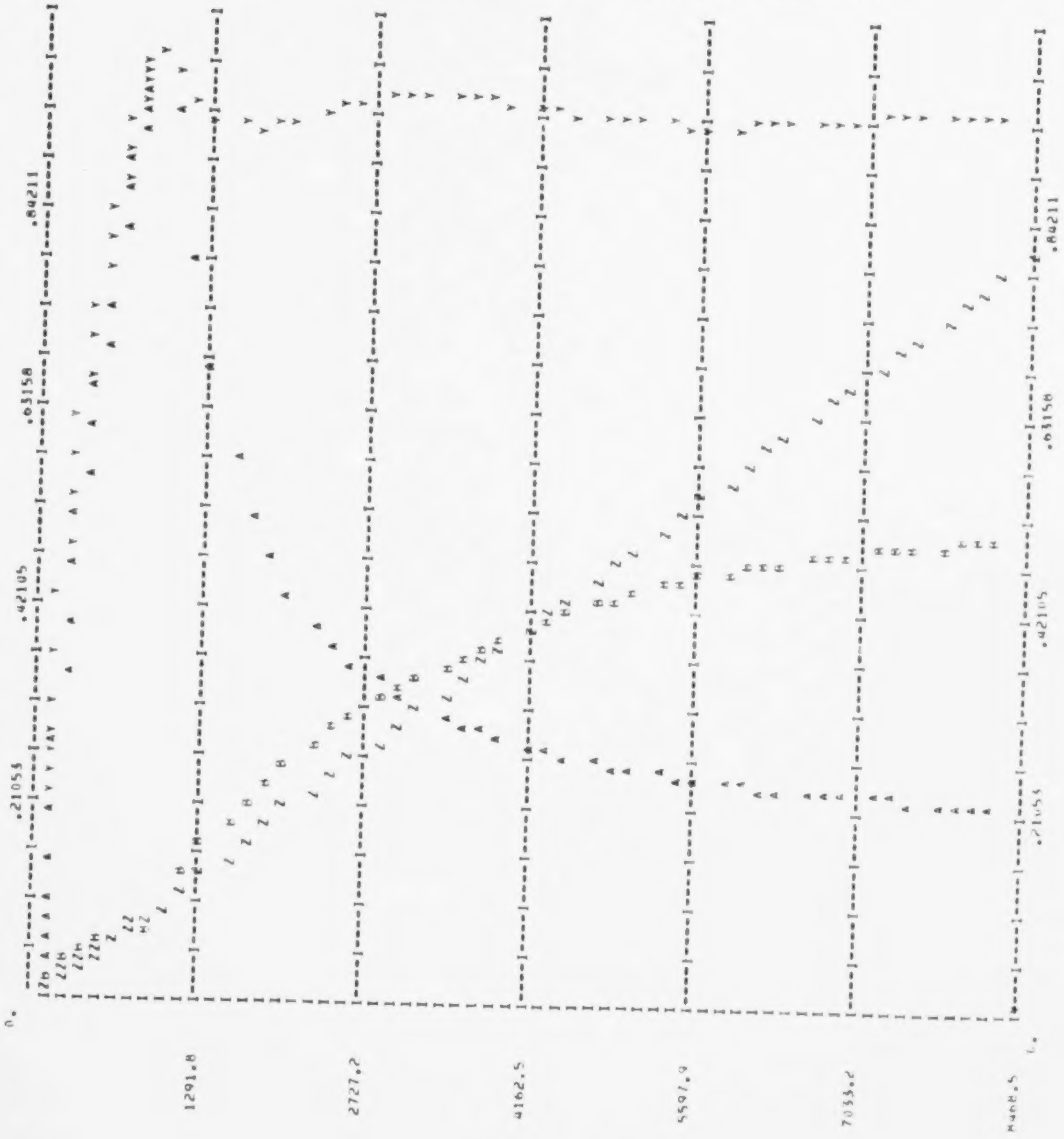
RUN J-F-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          913.52

                    DEPENDENT VARIABLES

SYMBOL              Y             R              C               Z
MAX PLOTTED     46.017        12.749         1.00000         851.39
MIN PLOTTED     0.            0.             0.              0.
REMARKS         VERT. DIST.     RADIUS       FLUID CONC.     HOR. DIST.
```



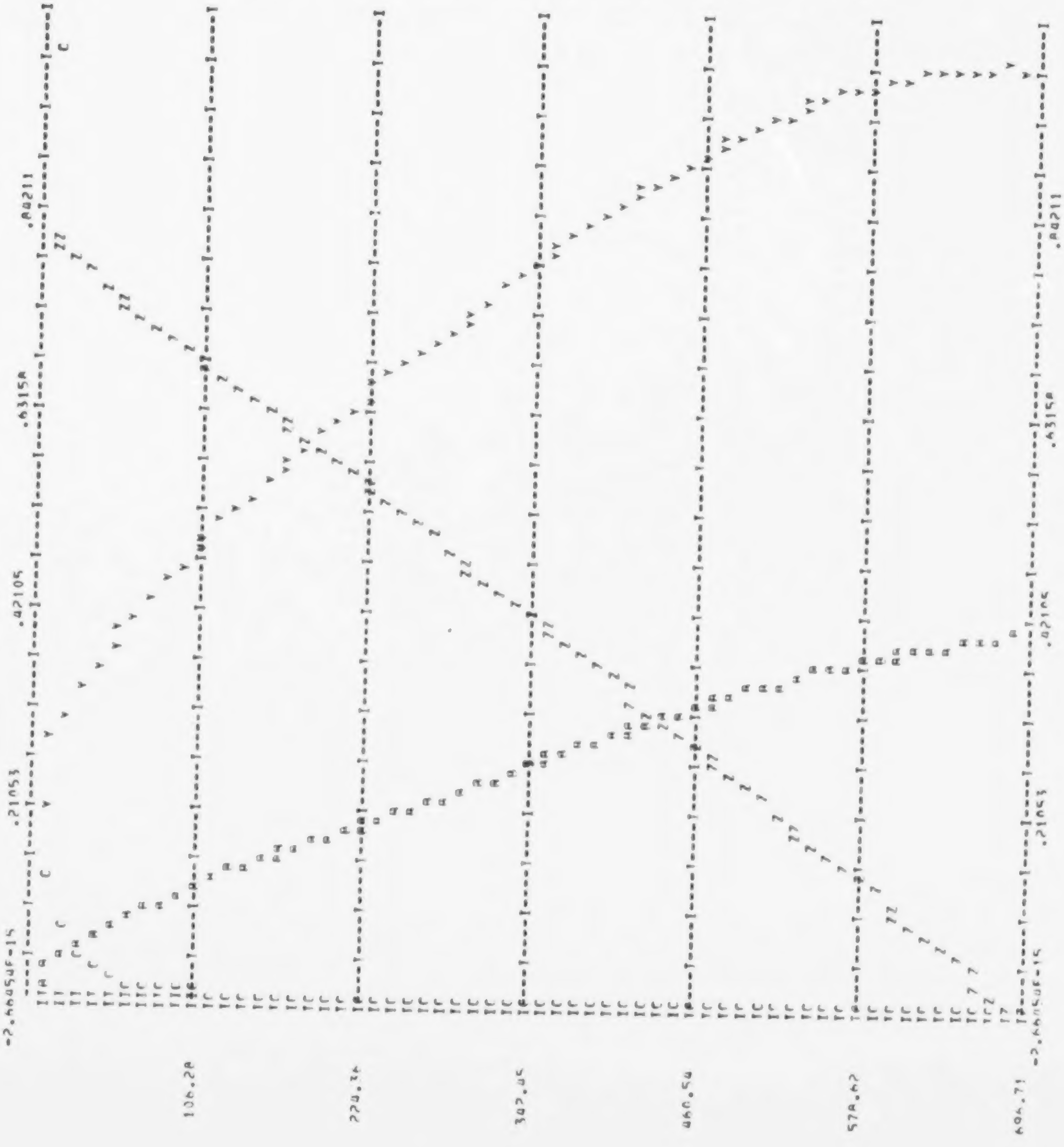
RUN J-F-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          8468.5

                        DEPENDENT VARIABLES

SYMBOL               A              B              Z              Y
MAX PLOTTED      12.692         91.619         8189.1         46.010
MIN PLOTTED      0.             0.             0.             0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



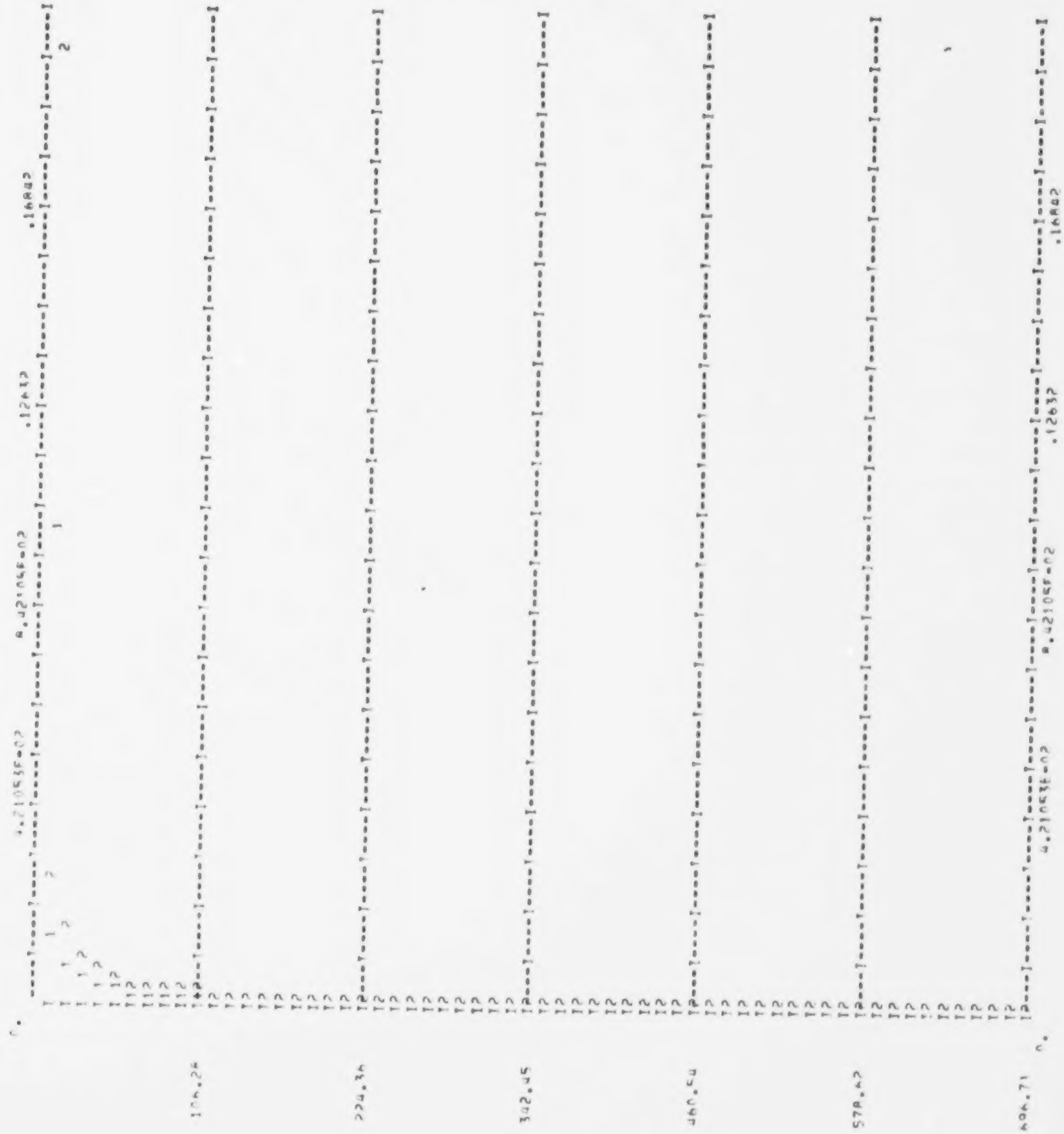
RUN J-2S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          696.71

                         DEPENDENT VARIABLES

SYMBOL              Y            R              C             Z
MAX PLOTTED      49.081       17.036          .70000        0.
MIN PLOTTED      0.           0.              0.           -1.60001E-03
REMARKS          VERT. DIST.   RADIUS         FLUID CONC.    HOR. DIST.
```



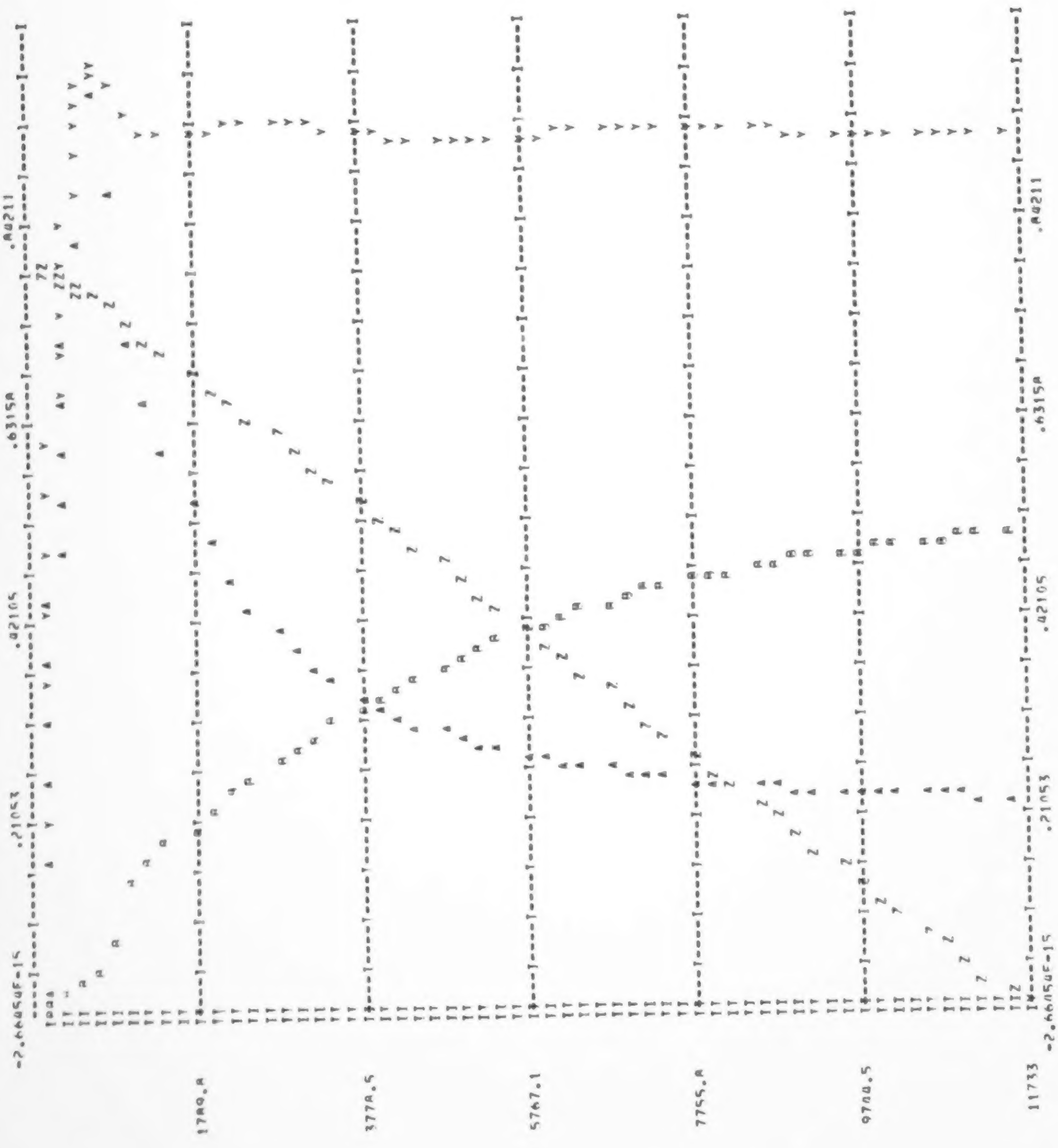
RUN J-2S-1

```
GRAPH OF WASTE  CONCENTRATIONS

RANGE OF X                              0.                  696.70706
RANGE OF CONCENTRATIONS PLOTTED         0.                  .20000000
```



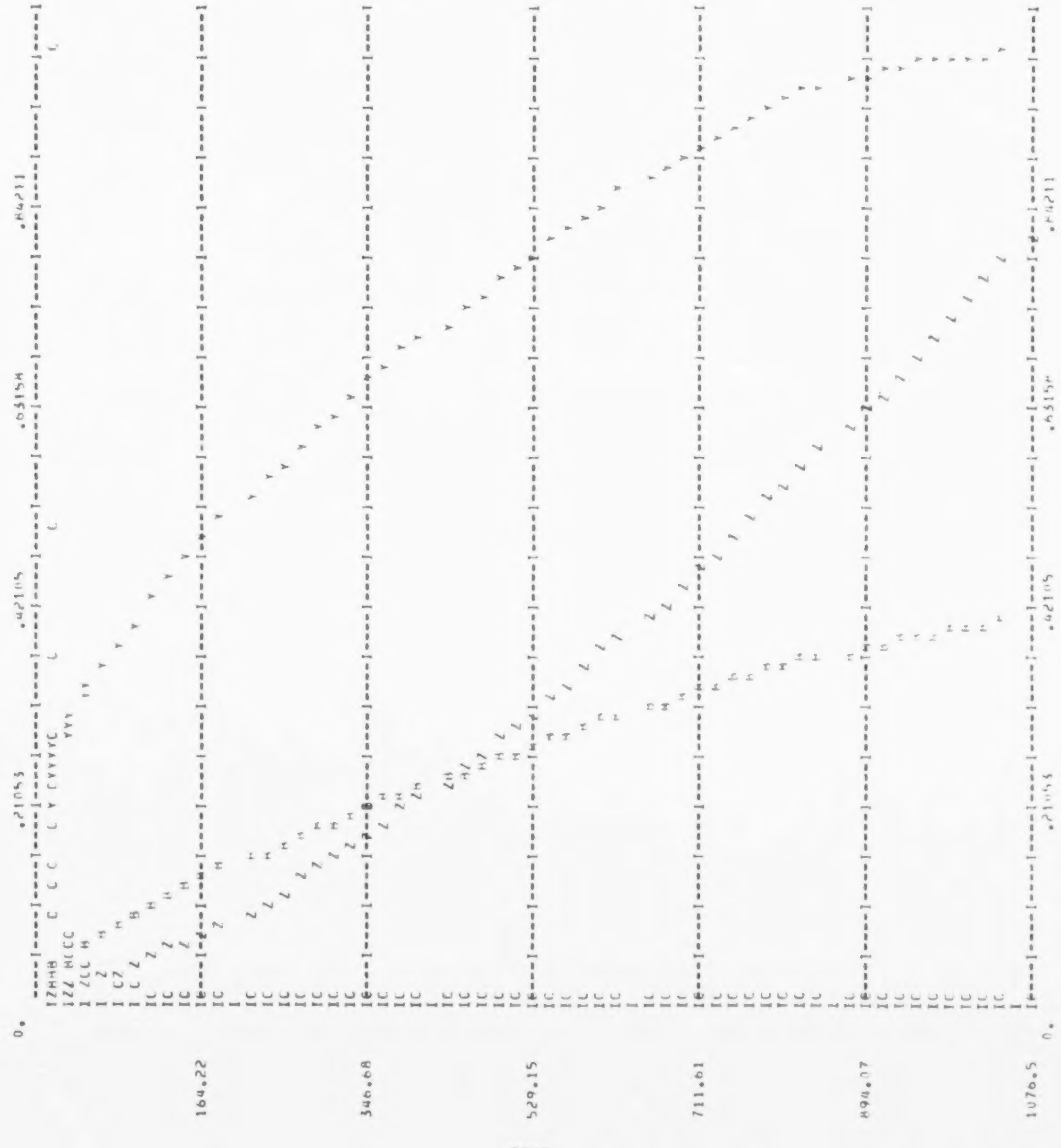
RUN J-2S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          11733

                        DEPENDENT VARIABLES

SYMBOL              A            B             Z            Y
MAX PLOTTED     16.874       193.93         0.           49.065
MIN PLOTTED     0.           0.            -2.94304E-02  0.
REMARKS         VERT. SIZE.   HOR. SIZE     HOR. DIST.   VERT. DIST.
```



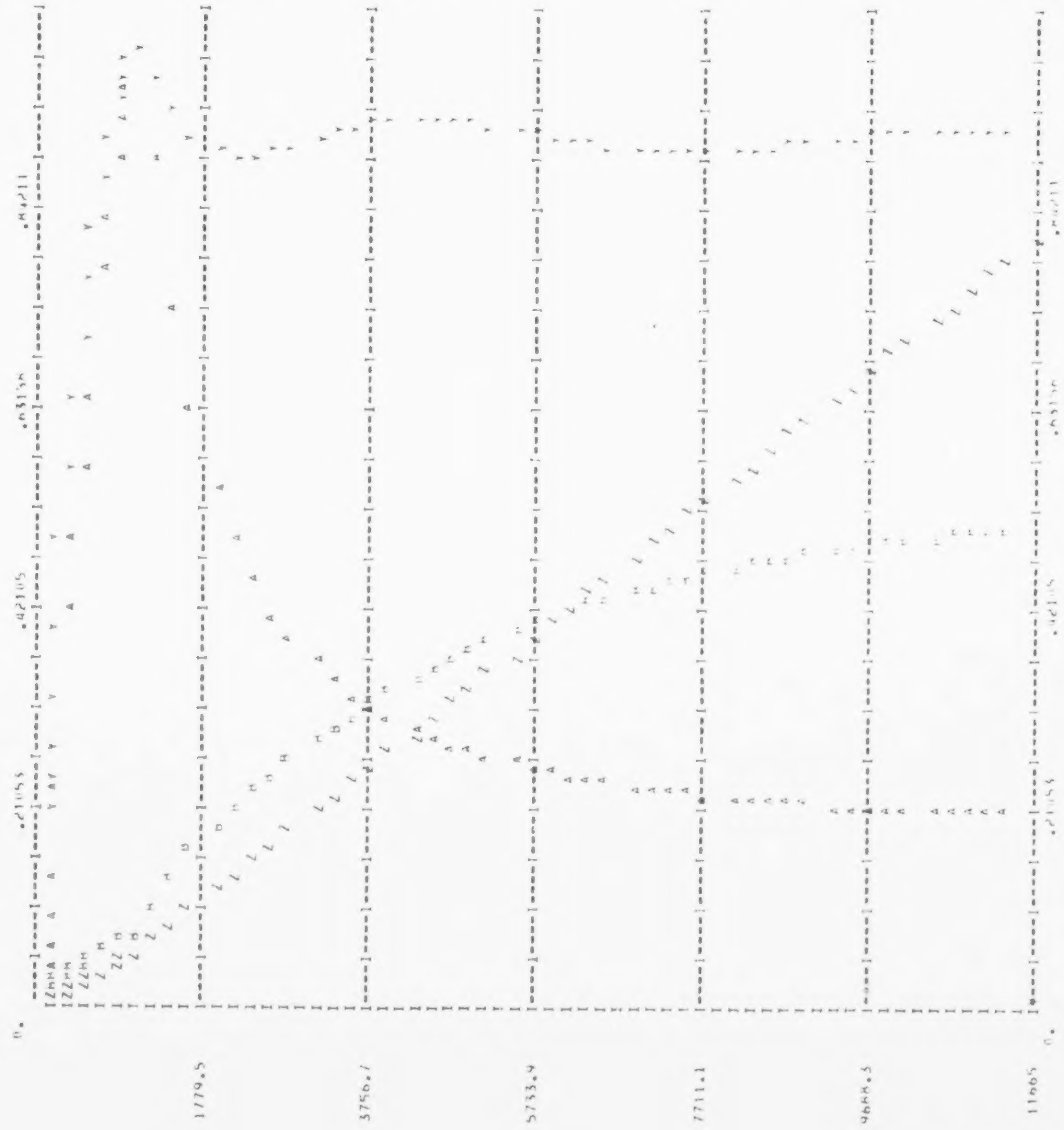
RUN J-4S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          1076.5

                         DEPENDENT VARIABLES

SYMBOL             Y            R             C            Z
MAX PLOTTED      47.682       15.161        .50000       75.158
MIN PLOTTED      0.           0.            0.           0.
REMARKS          VERT. DIST.   RADIUS       FLUID CONC.   HOR. DIST.
```



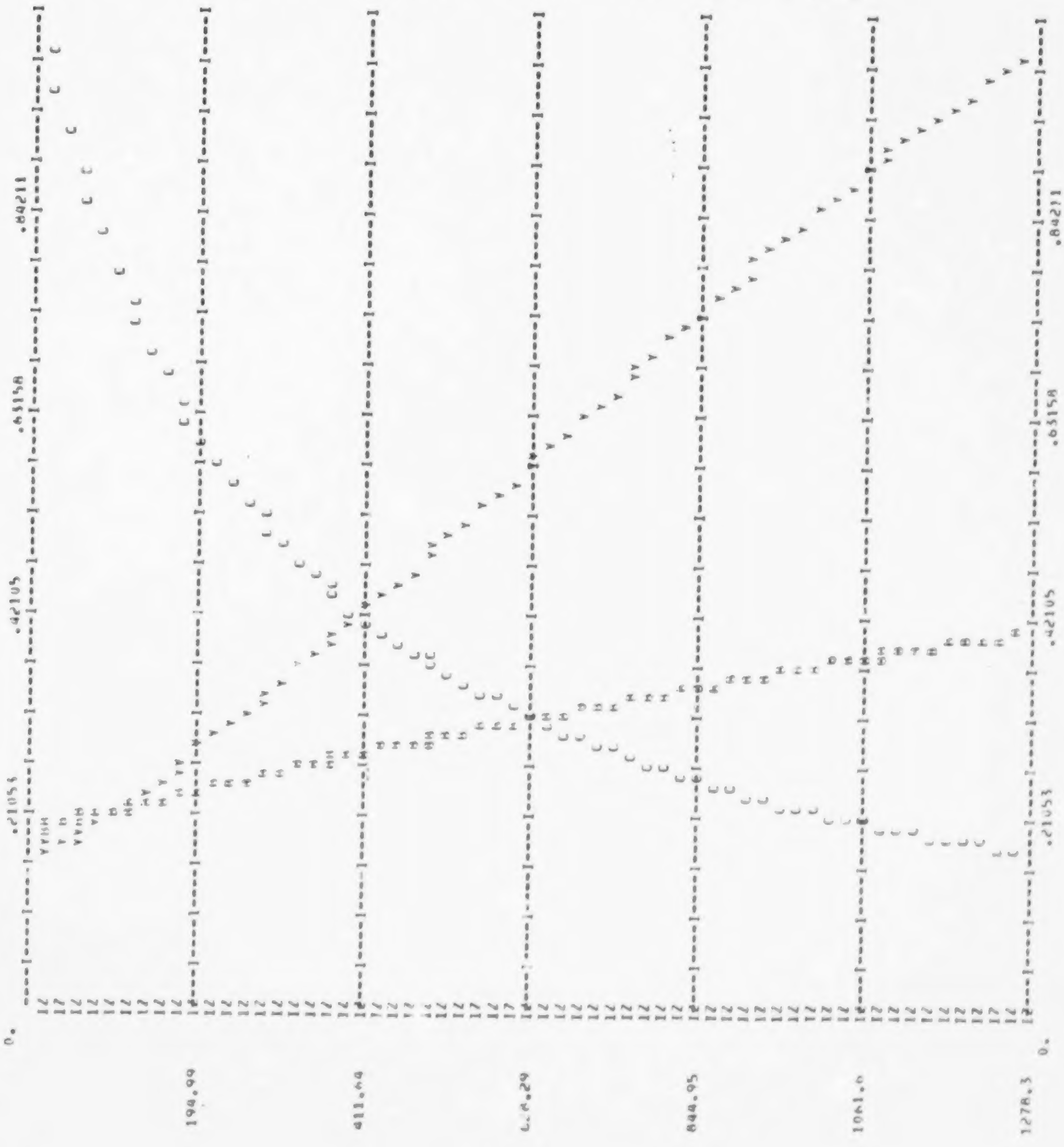
RUN J-4S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.            11665

                 DEPENDENT VARIABLES

SYMBOL              A            B             Z            Y
MAX PLOTTED      15.161       104.37        1125.2       67.682
MIN PLOTTED      0.           0.            0.           0.
REMARKS          VERT. SIZE.  HOR. SIZE     HOR. DIST.   VERT. DIST.
```

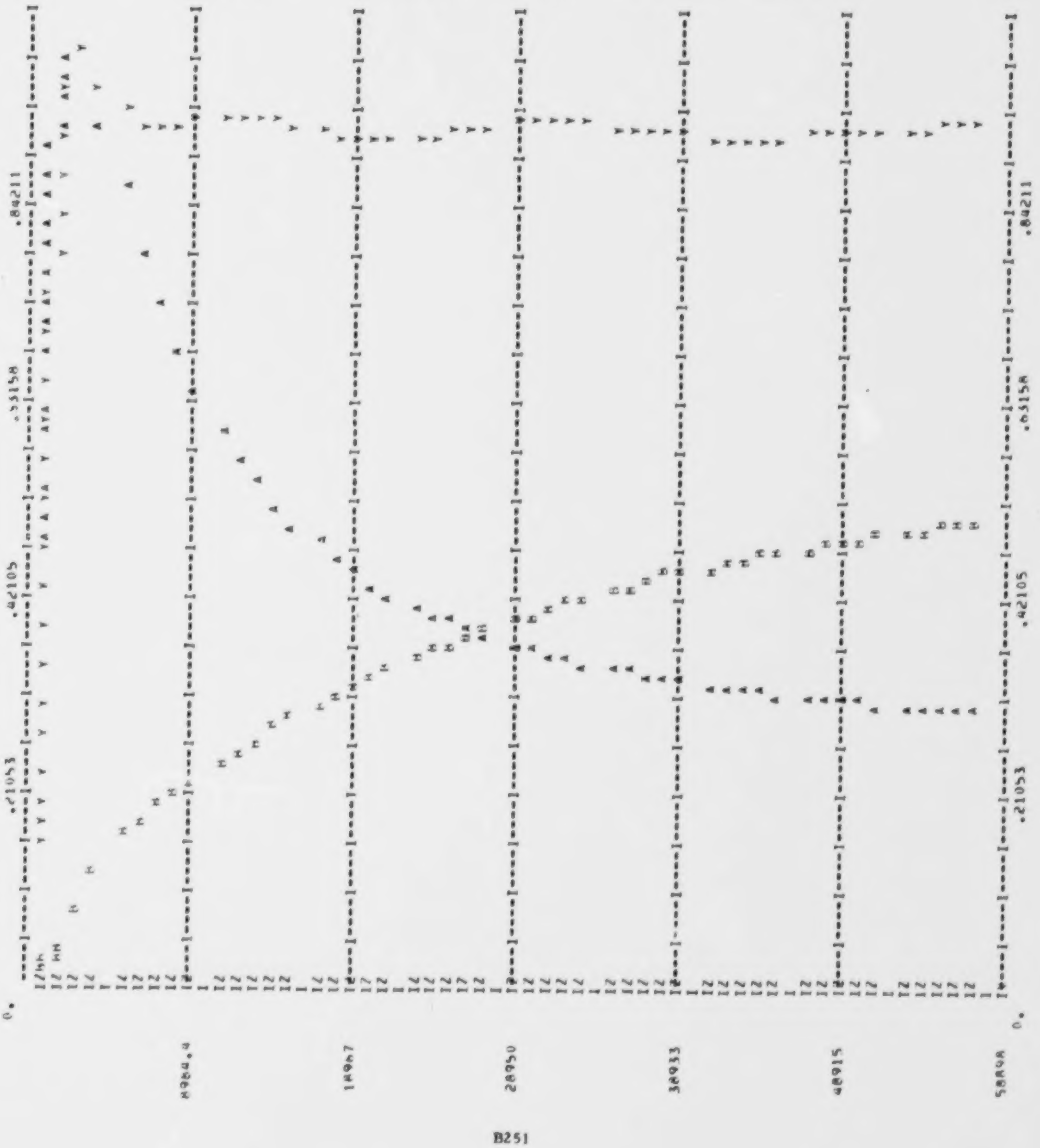


RUN W-L-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          1278.3

                        DEPENDENT VARIABLES

SYMBOL            Y              R            C              Z
MAX PLOTTED     53.709         44.971       1.99619E-03     0.
MIN PLOTTED     0.             0.           0.              0.
REMARKS         VERT. DIST.    RADIUS       FLUID CONC.     HOR. DIST.
```

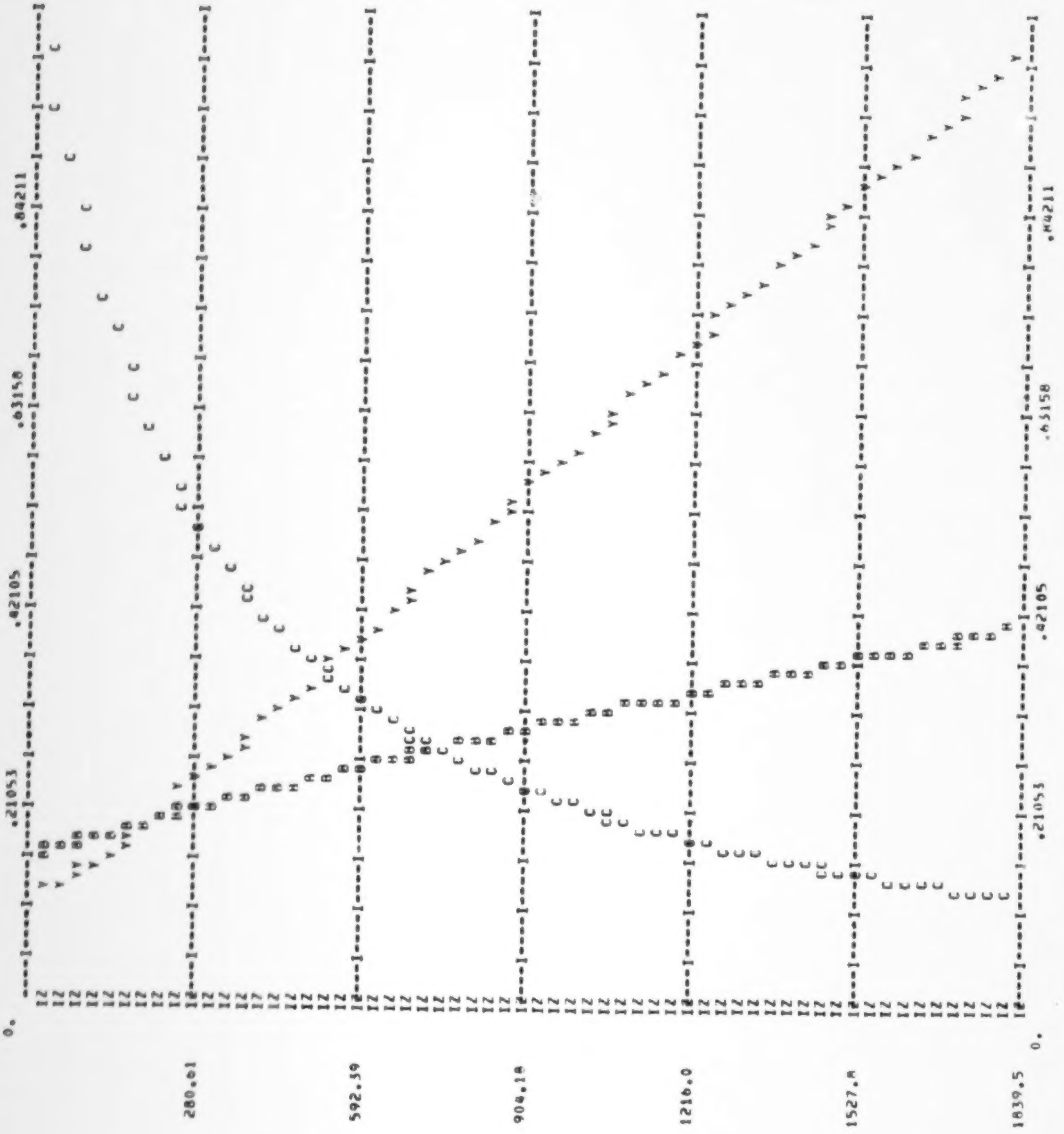


```
                              RUN W-L-1
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.            58898

                          DEPENDENT VARIABLES

SYMBOL              A                B              Z               Y
MAX PLOTTED      22.258           718.80          0.            57.689
MIN PLOTTED      0.               0.              0.            0.
REMARKS          VERT. SIZE.      HOR. SIZE      HOR. DIST.    VERT. DIST.
```



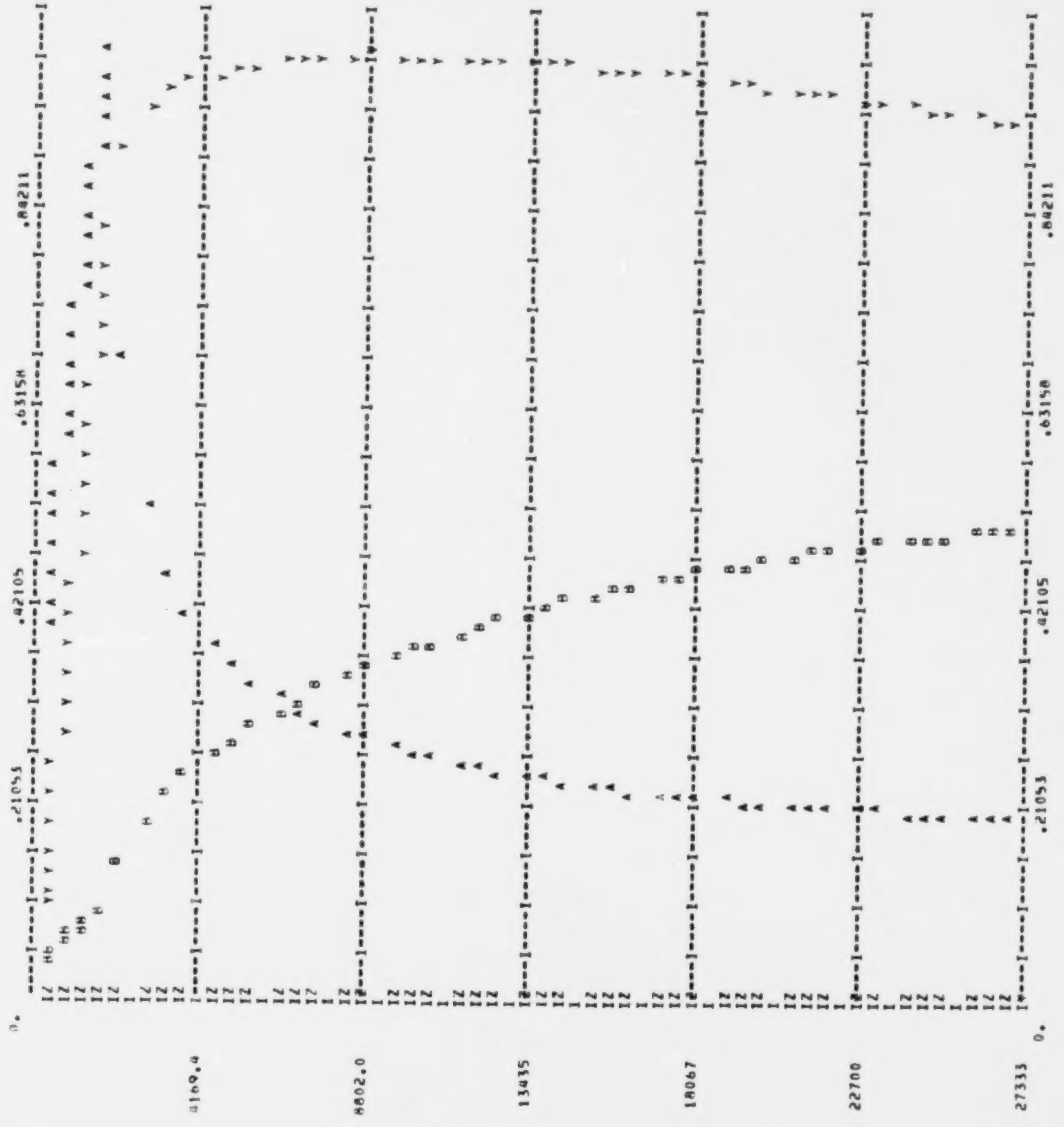
RUN W-L-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          1839.5

                    DEPENDENT VARIABLES

SYMBOL              Y             B              C             Z
MAX PLOTTED      77.189        54.564       1.99619E-03    0.
MIN PLOTTED      0.            0.           0.             0.
REMARKS          VERT. DIST.    RADIUS      FLUID CONC.    HOR. DIST.
```



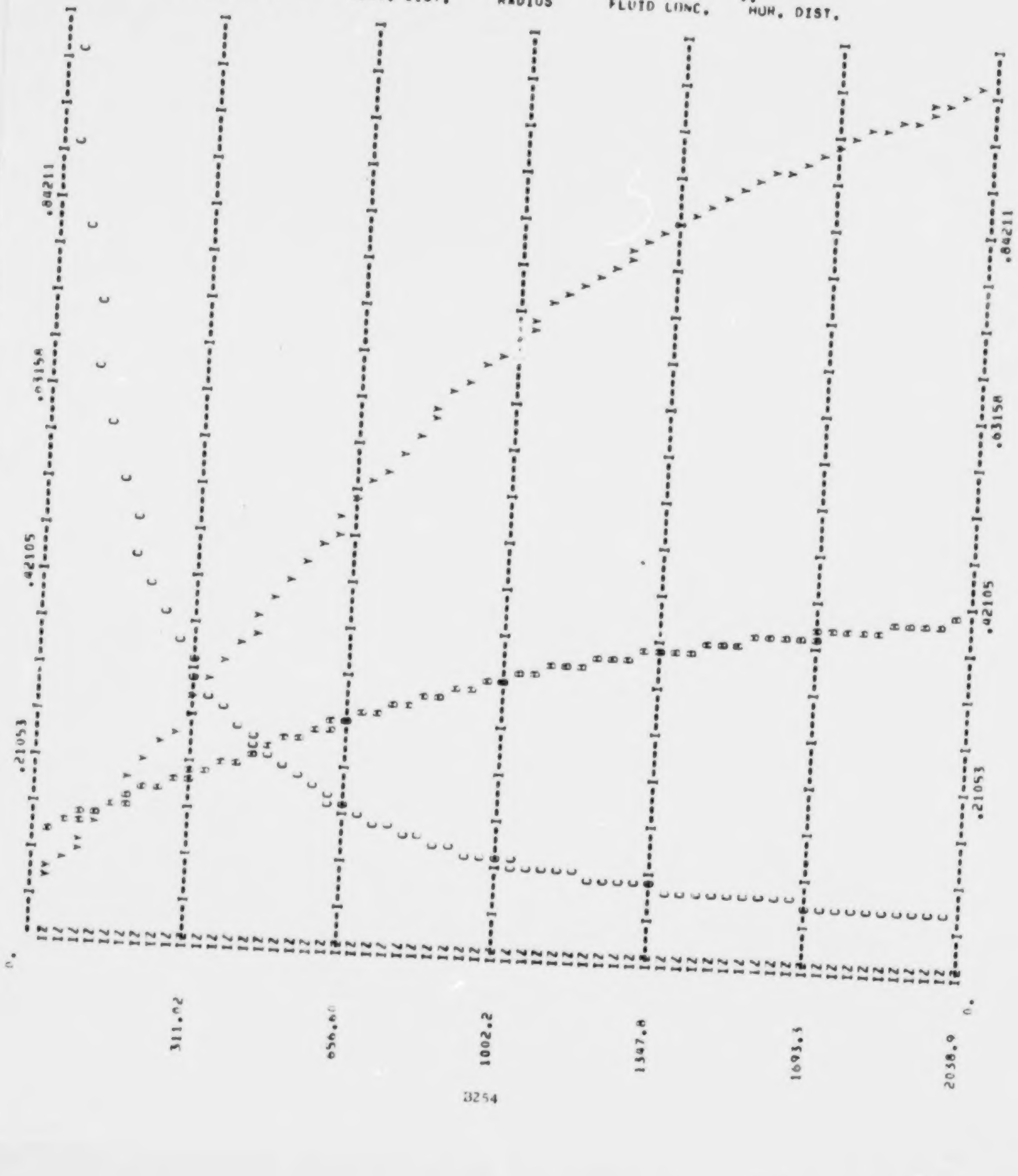
RUN V-L-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          27333

                         DEPENDENT VARIABLES

SYMBOL              A              B             Z             Y
MAX PLOTTED      27.070         290.08        0.            93.813
MIN PLOTTED     0.             0.            0.            0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```

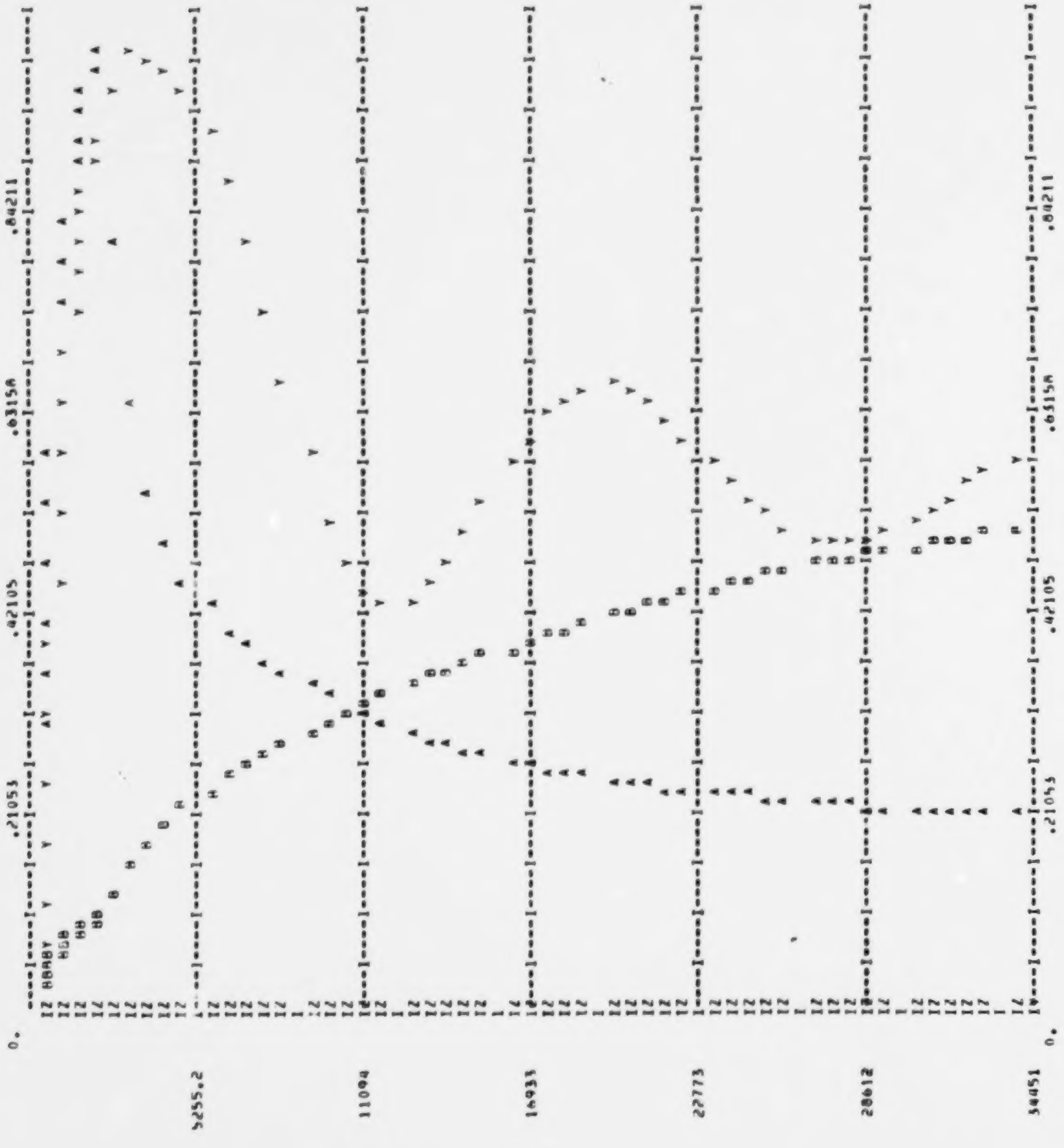


RUN W-L-3

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          2038.9

                         DEPENDENT VARIABLES
SYMBOL
MAX PLOTTED        Y             B               C               Z
MIN PLOTTED      80.655        45.915       4.99048E-03     0.
REMARKS          0.          0.             0.              0.
                 VERT. DIST.   RADIUS       FLUID CONC.     HOR. DIST.
```

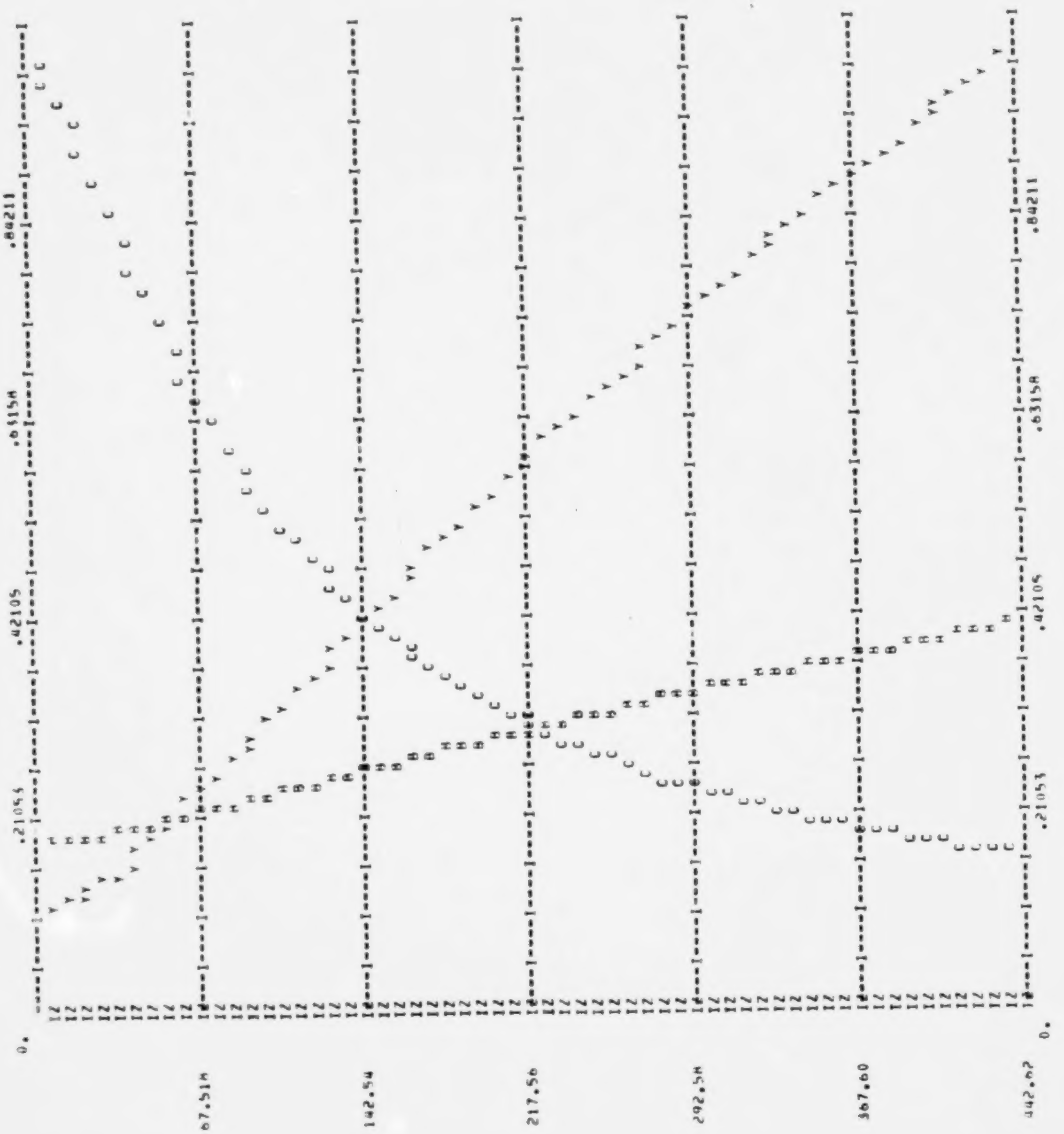


```
                                   RUN W-L-3
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.           34451

                              DEPENDENT VARIABLES

SYMBOL              A              B              Z              Y
MAX PLOTTED      22.744         238.86         0.            87.621
MIN PLOTTED      0.             0.             0.            0.
REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.    VERT. DIST.
```



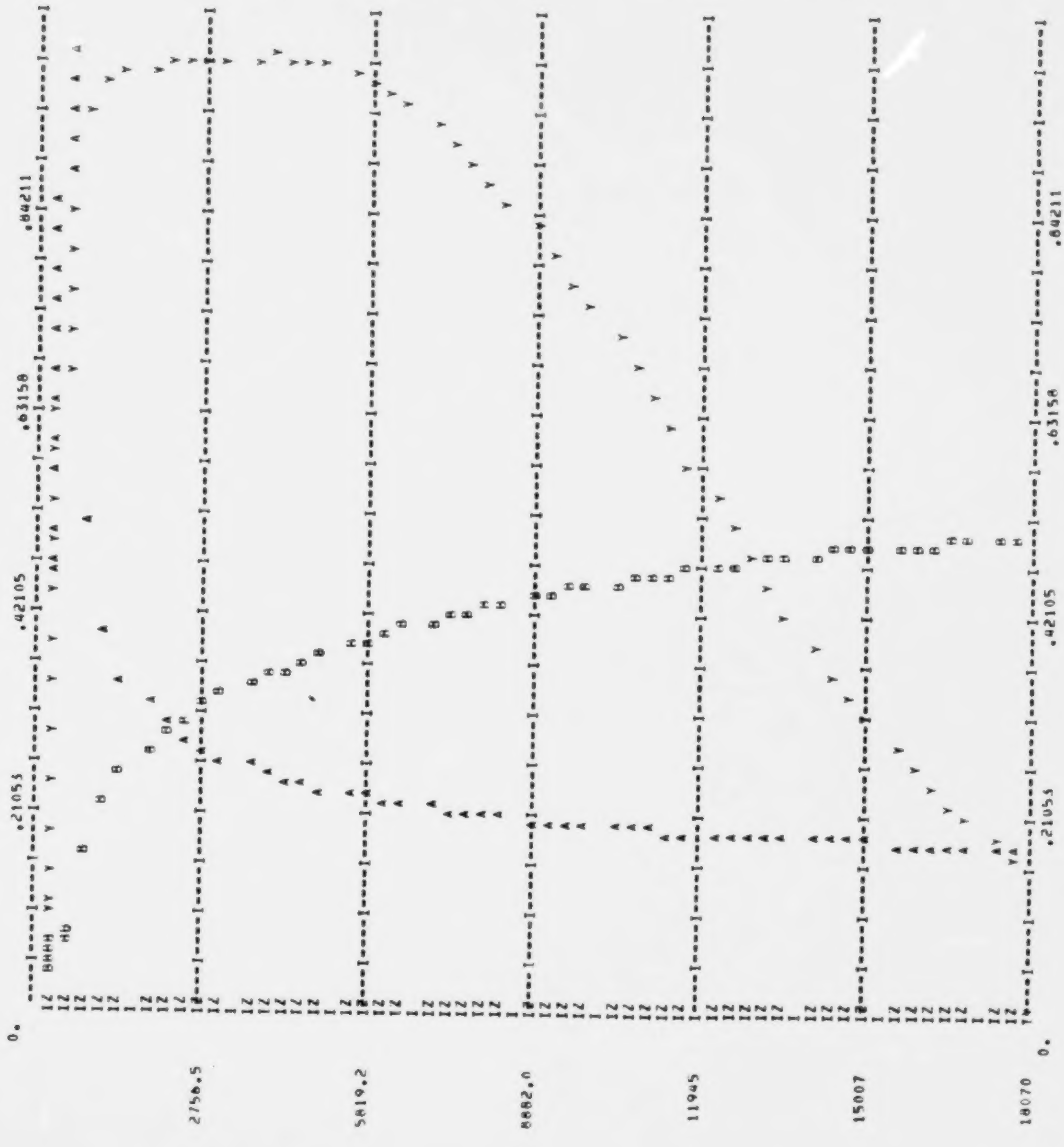
RUN W-L-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          442.62

                    DEPENDENT VARIABLES

SYMBOL              Y              H              C               Z
MAX PLOTTED       80.404         47.118         1.99619E-02     0.
MIN PLOTTED       0.             0.             0.              0.
REMARKS           VERT. DIST.    RADIUS         FLUID CONC.     HOR. DIST.
```



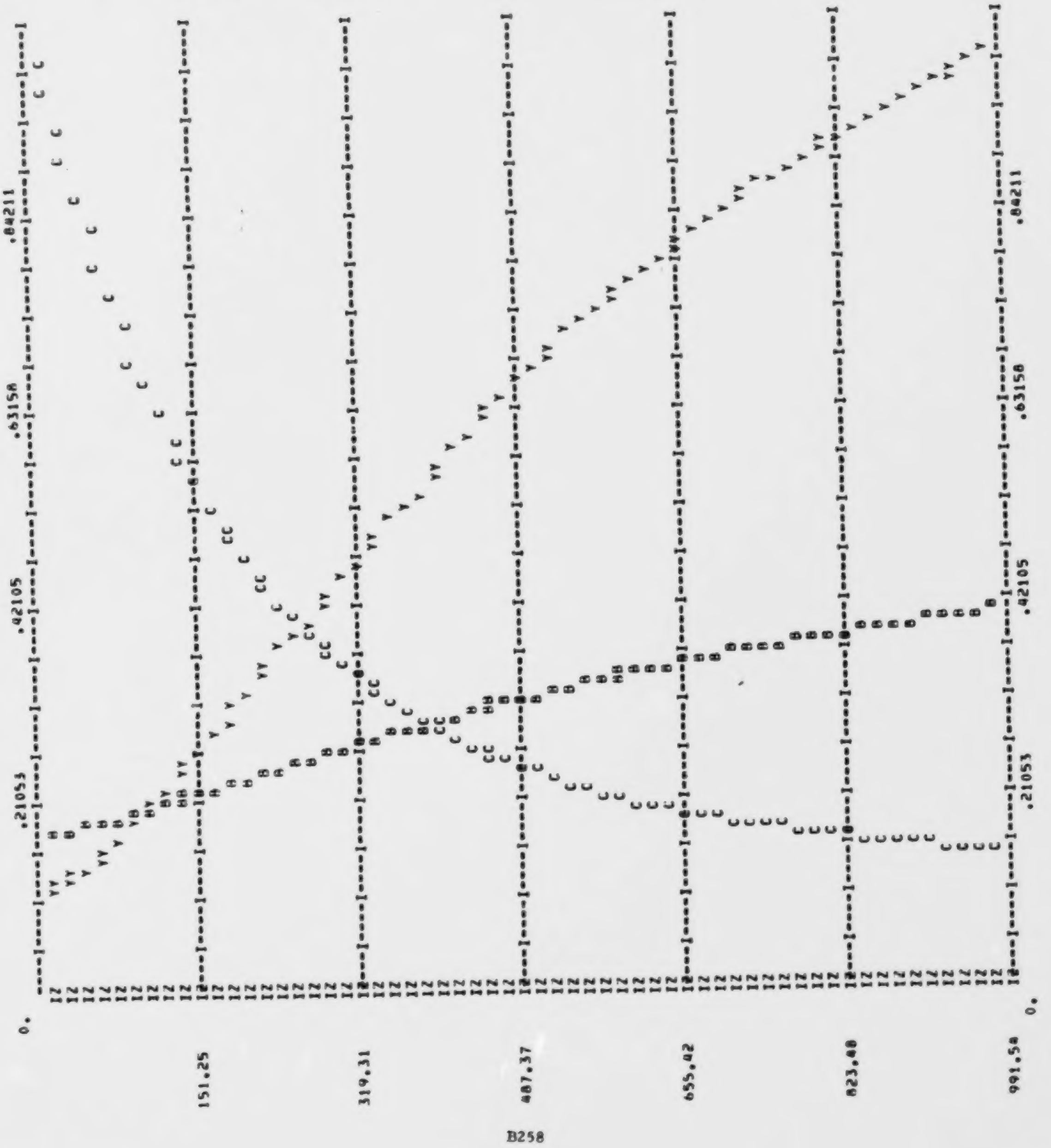
RUN W-L-4

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.           18070

                          DEPENDENT VARIABLES

SYMBOL                A              B              Z              Y
MAX PLOTTED       23.385         282.65         0.             94.540
MIN PLOTTED       0.             0.             0.             0.
REMARKS           VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



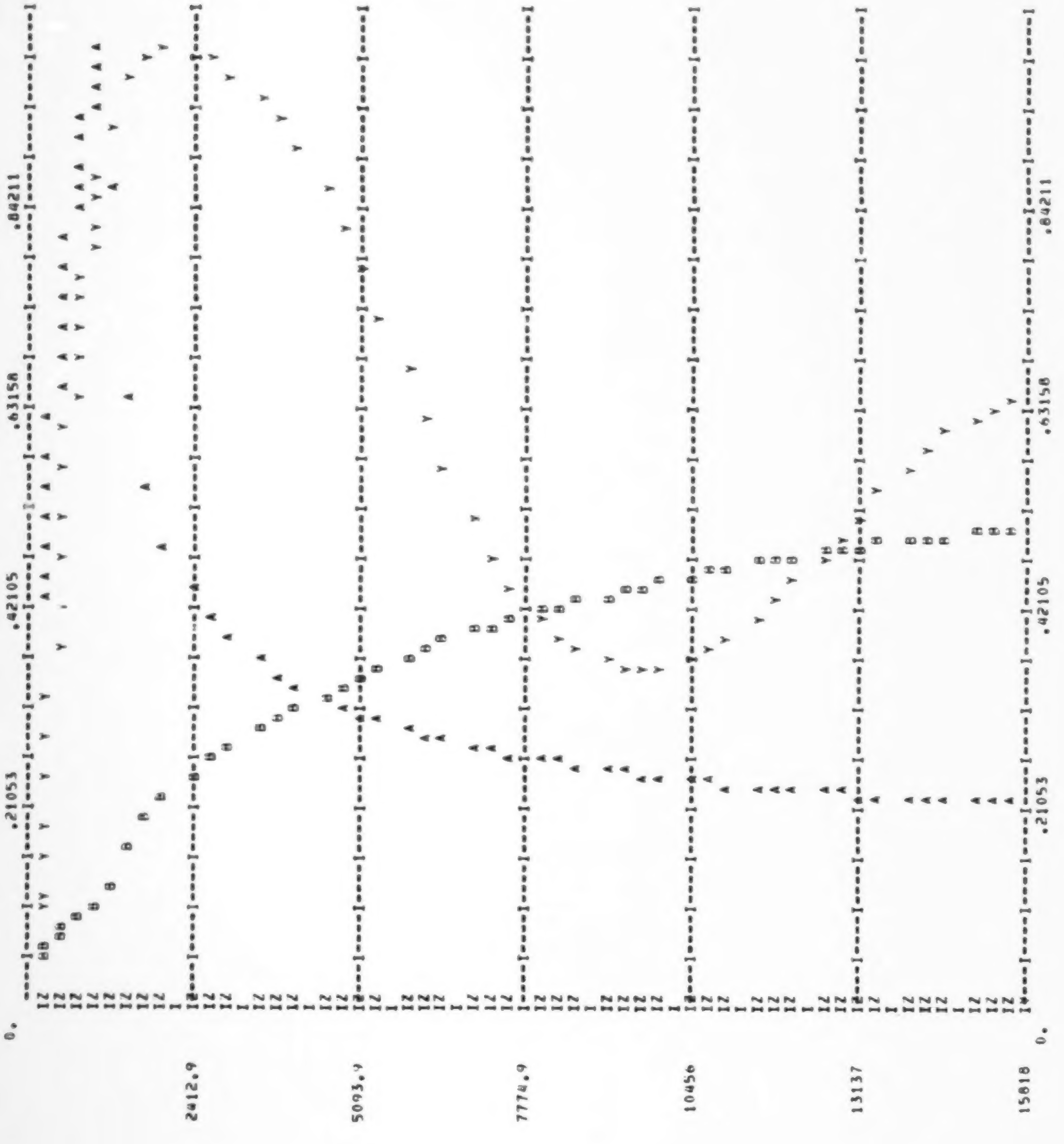
RUN W-L-5

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          991.54

                      DEPENDENT VARIABLES

SYMBOL              Y              B             C              Z
MAX PLOTTED     78.885         49.953        2.99429E-03     0.
MIN PLOTTED     0.             0.            0.              0.
REMARKS         VERT. DIST.     RADIUS       FLUID CONC.     HOR. DIST.
```



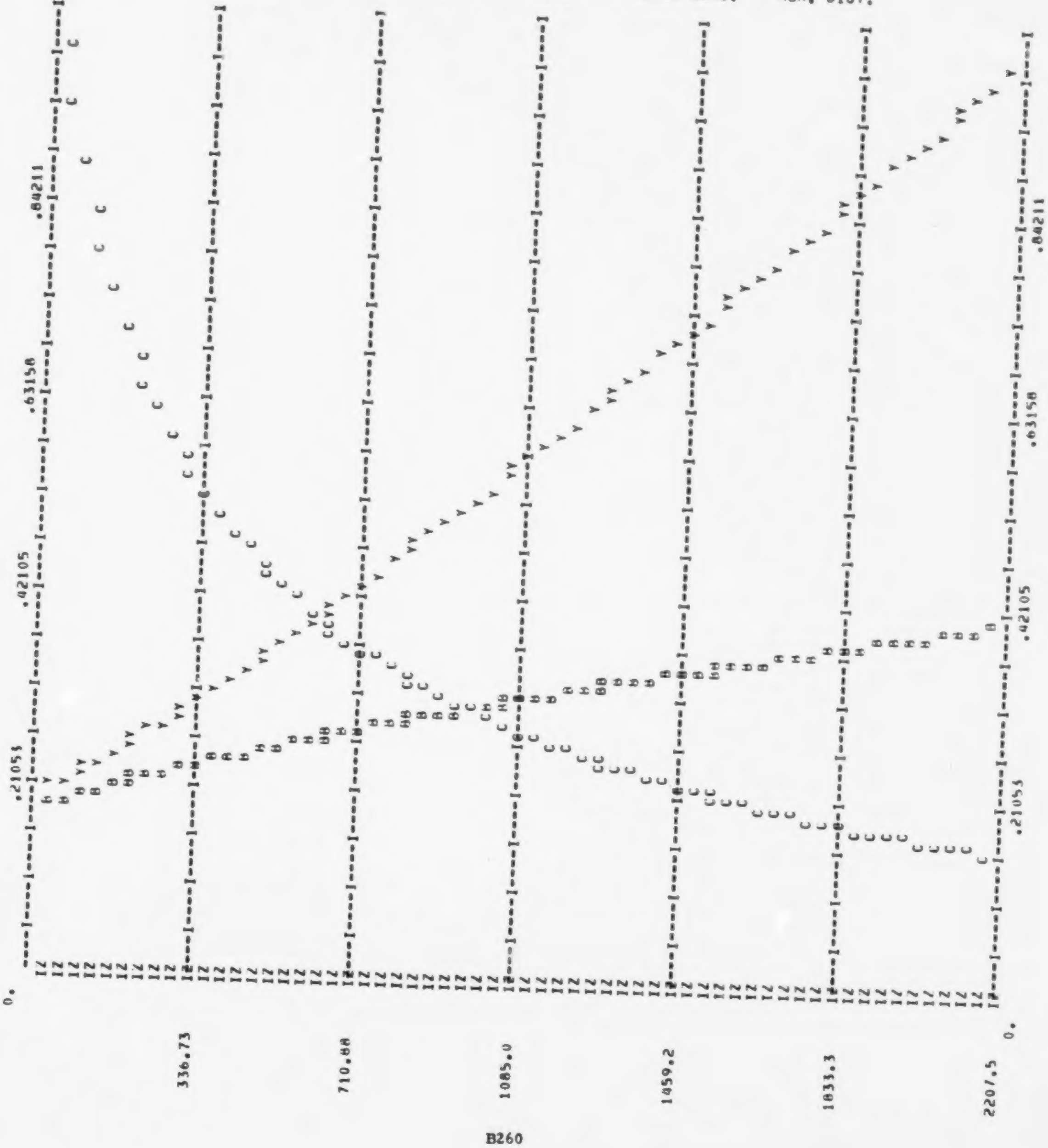
RUN W-L-5

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.           15818

                         DEPENDENT VARIABLES

SYMBOL              A              B              Z              Y
MAX PLOTTED     24.680         244.41         0.             89.239
MIN PLOTTED     0.             0.             0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```

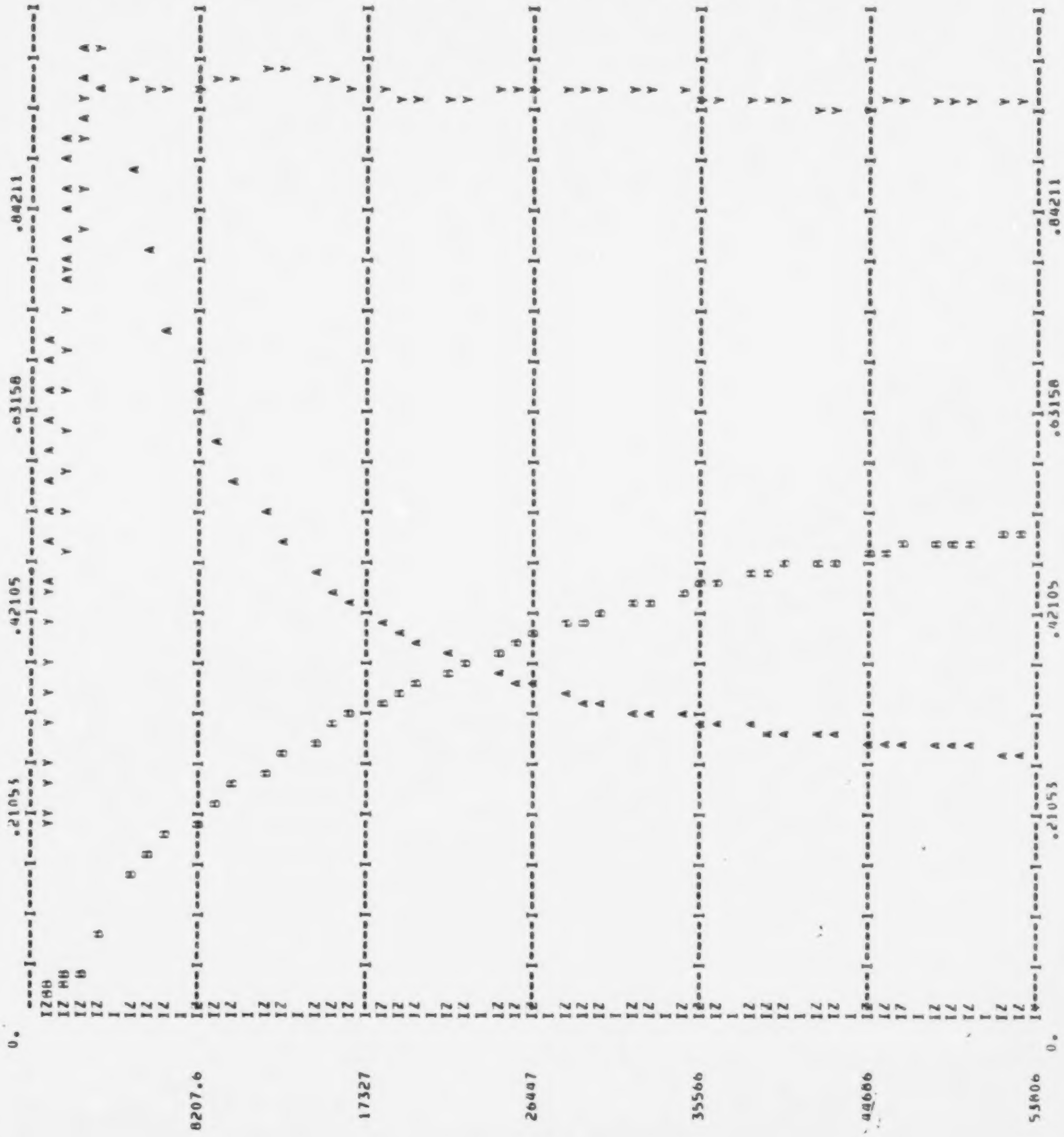


RUN W-S-1

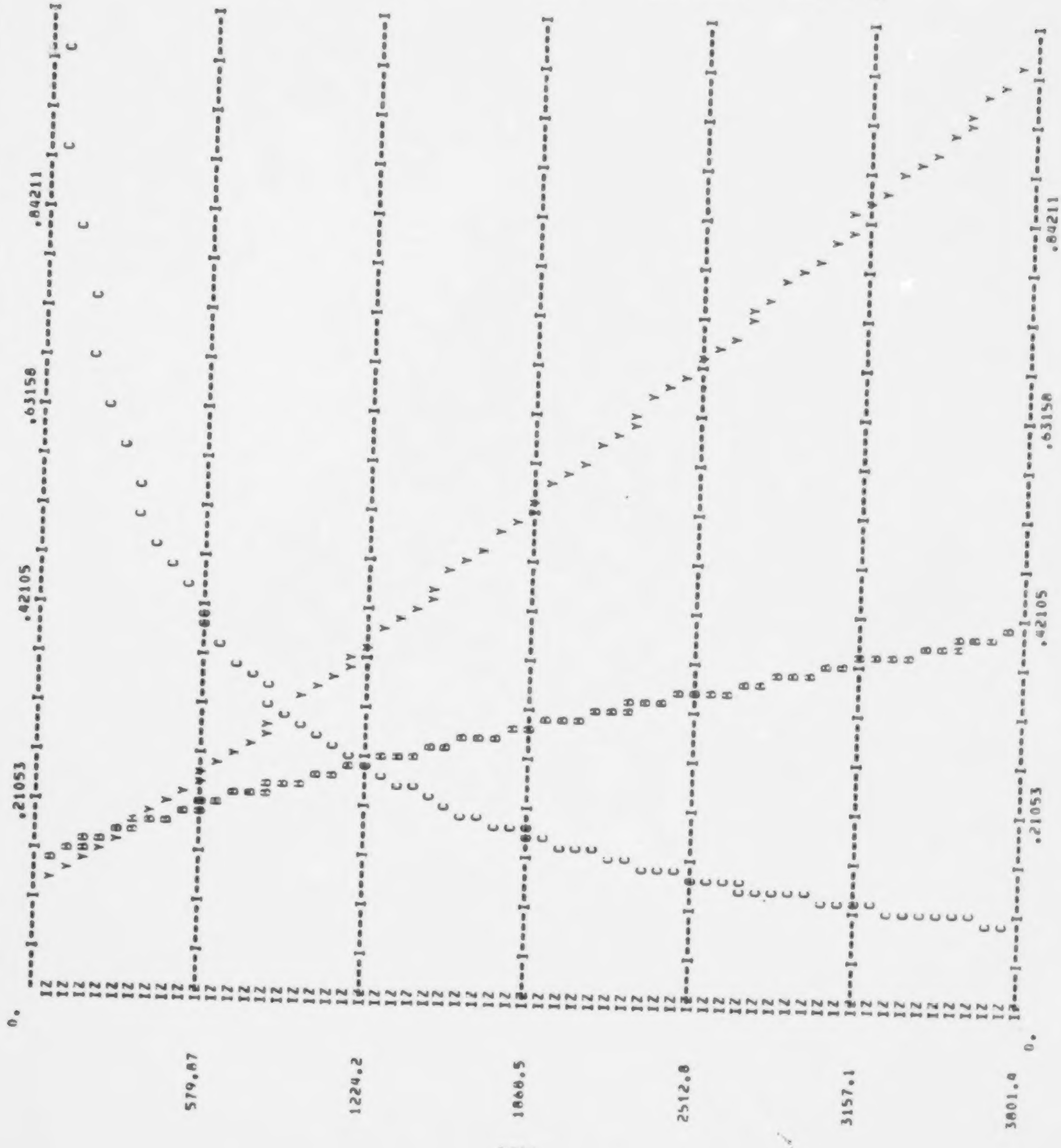
```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          2207.5

                         DEPENDENT VARIABLES

SYMBOL                 Y               B              C              Z
MAX PLOTTED         44.172          47.451       2.12095E-03      0.
MIN PLOTTED         0.              0.           0.               0.
REMARKS             VERT. DIST.     RADIUS       FLUID CONC.      HOR. DIST.
```



```
                                   RUN W-S-1
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.            53806

                          DEPENDENT VARIABLES

SYMBOL              A              B              Z               Y
MAX PLOTTED     23.726         626.49          0.             46.604
MIN PLOTTED     0.             0.              0.             0.
REMARKS         VERT. SIZE.    HOR. SIZE     HOR. DIST.    VERT. DIST.
```

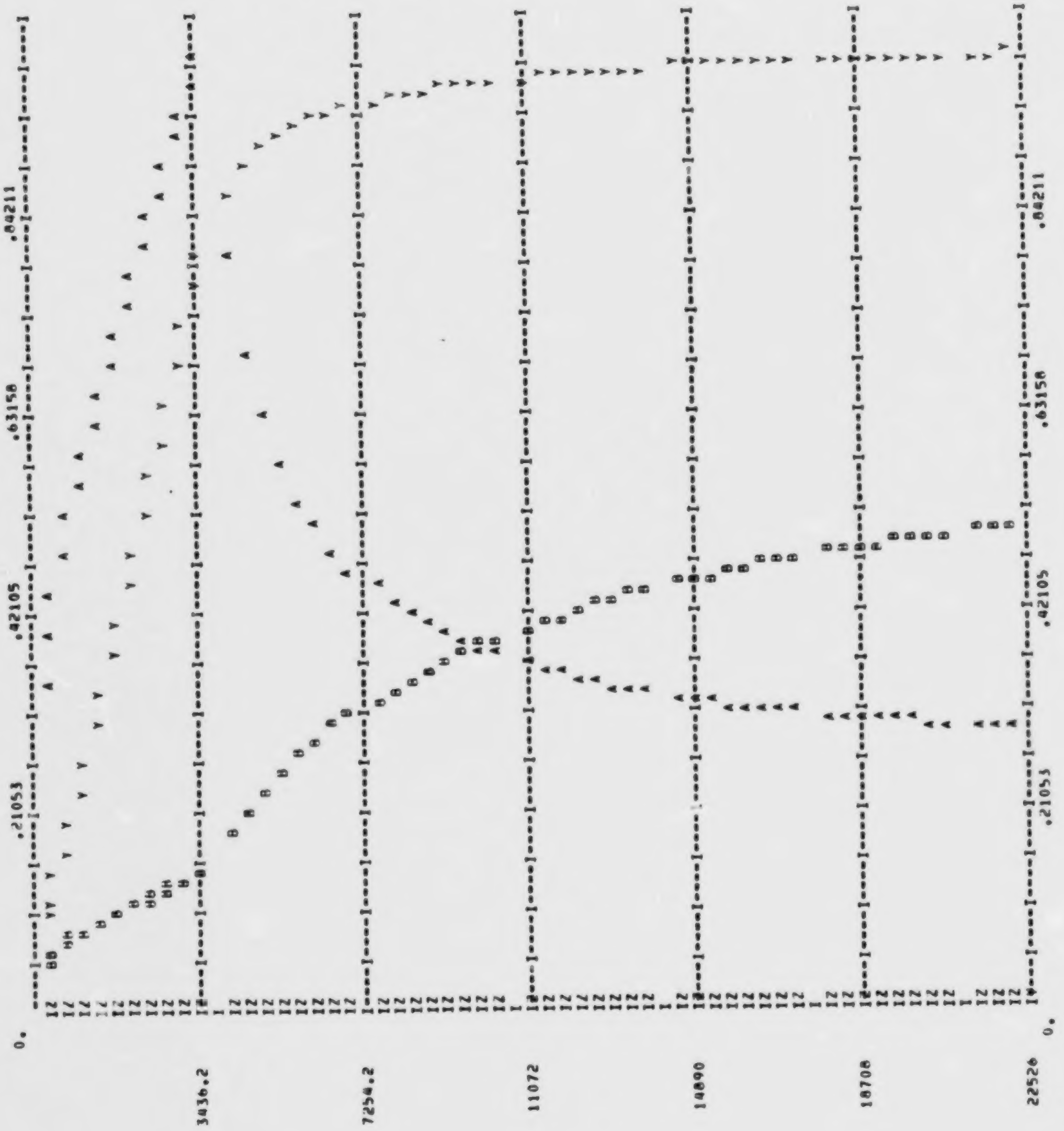


```
                              RUN W-S-2
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE     0.          3801.4

                          DEPENDENT VARIABLES

SYMBOL              Y             B              C               Z
MAX PLOTTED      74.056        61.491       2.12095E-03      0.
MIN PLOTTED      0.            0.           0.               0.
REMARKS          VERT. DIST.   RADIUS       FLUID CONC.      HOR. DIST.
```

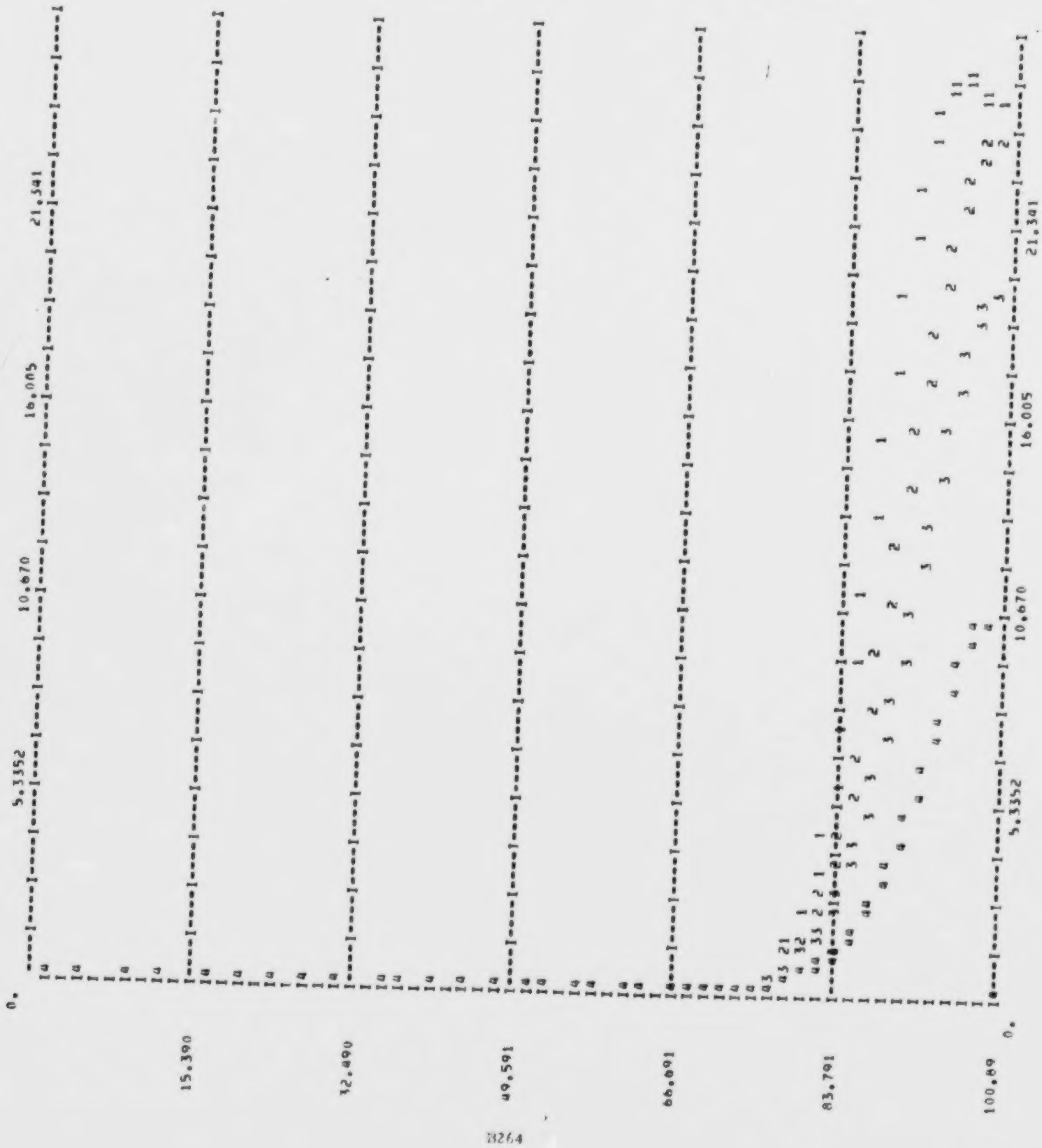


RUN W-S-2

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.          22526

                          DEPENDENT VARIABLES

SYMBOL              A             B            Z              Y
MAX PLOTTED     30.746        214.84       0.            92.605
MIN PLOTTED     0.            0.           0.            0.
REMARKS         VERT. SIZE.   HOR. SIZE    HOR. DIST.    VERT. DIST.
```

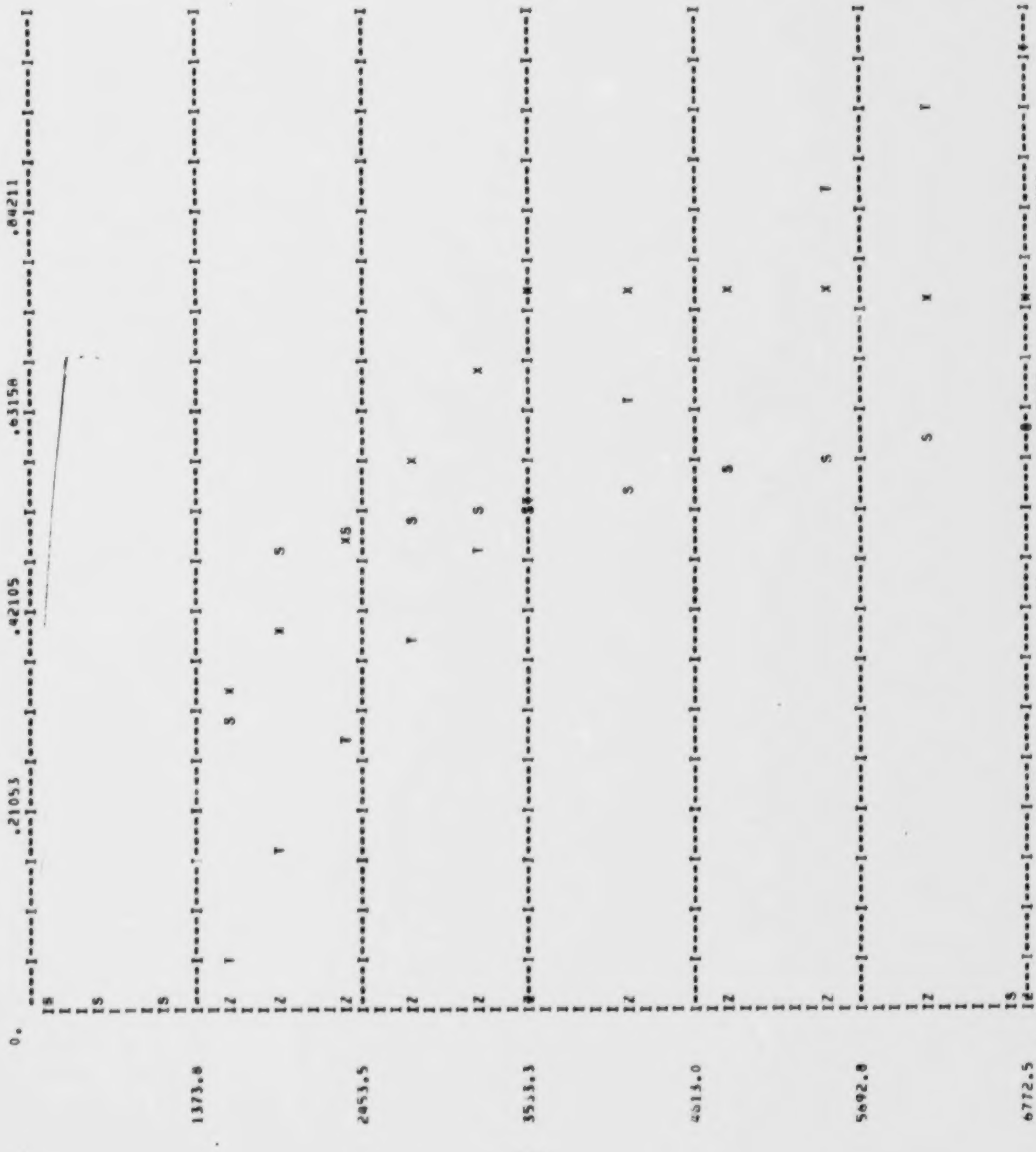


```
                                   RUN W-S-2
                          GRAPH OF    COO    VS Y AT TIMES
 4229.3132                4865.1143          5500.9153              6772.5175

        RANGE OF     Y    PLOTTED         0.                       100.89149
        RANGE OF    COO   PLOTTED         0.                       25.342014
```



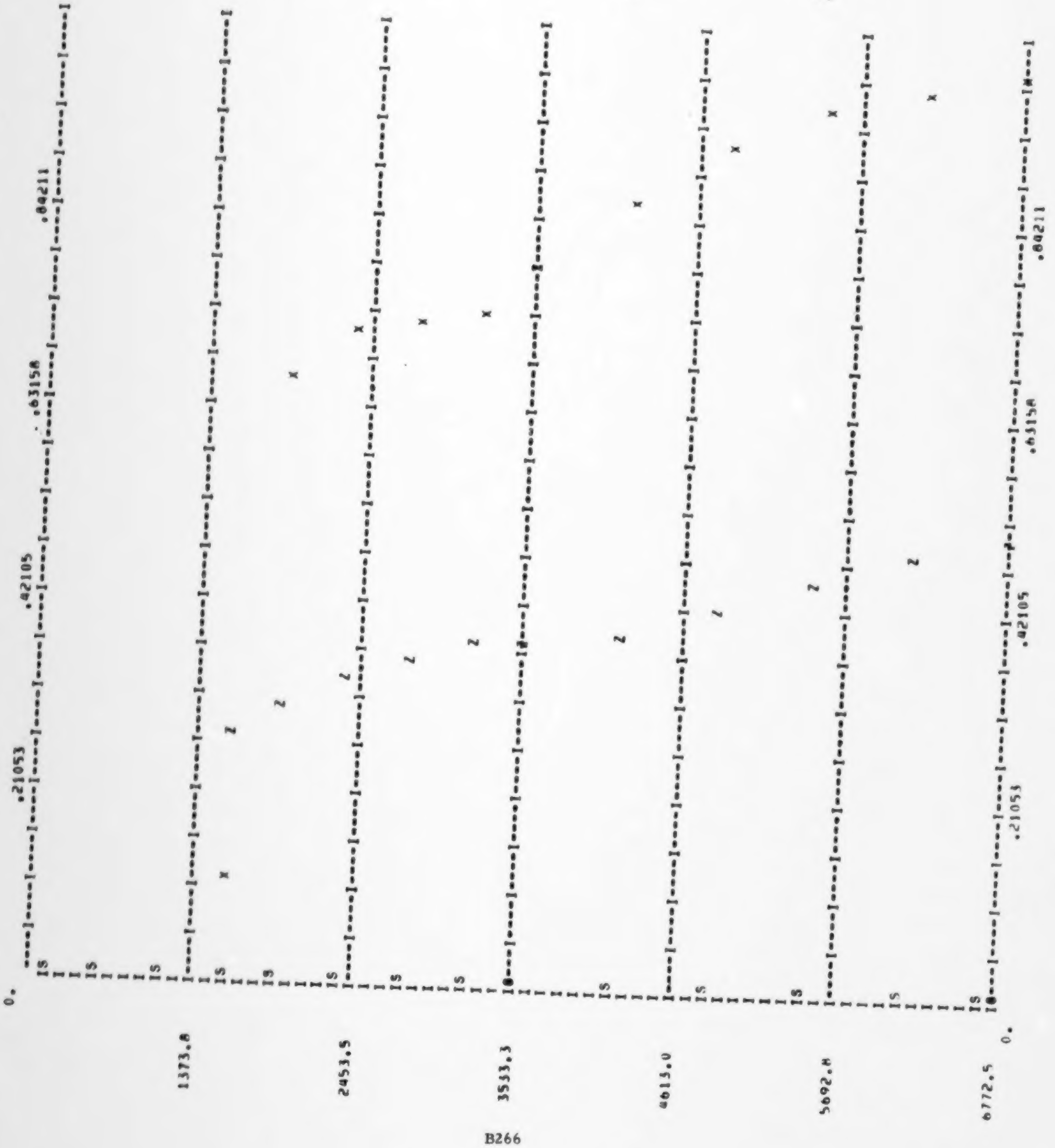
RUN W-S-2

```
PLOT OF TOT BODY MAT (T) CENTROID LOCATIONS (X,Z) AND SIZE (S) VS TIME

TIME RANGE              402.01358            6772.5175
MAXIMUM T,X,Z,S         659.51384            28541.752          0.                  701.27565
MINIMUM T,X,Z,S       0.                   0.                   0.                0.
```



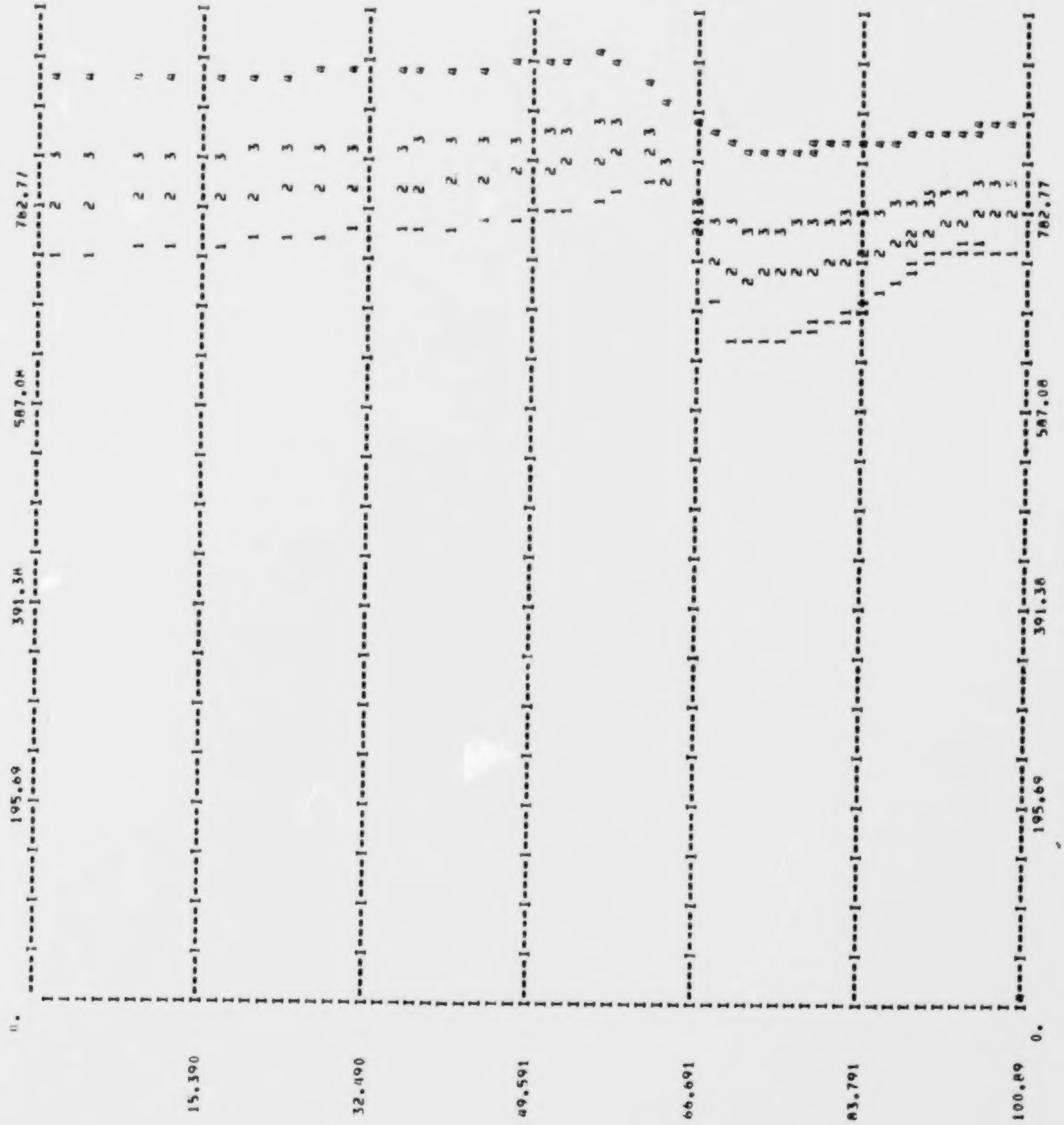
RUN W-S-2

```
PLOT OF BOUNDARY MATERIAL SIGMAX AND Z (X,Z) AND SIGMAXZ (S) VS. TIME
TIME RANGE=             402.01358          6772.5175
MAXIMUM X,Z,S           958378.71          15772.404          0.
MINIMUM X,Z,S           0.                 0.                 0.
```



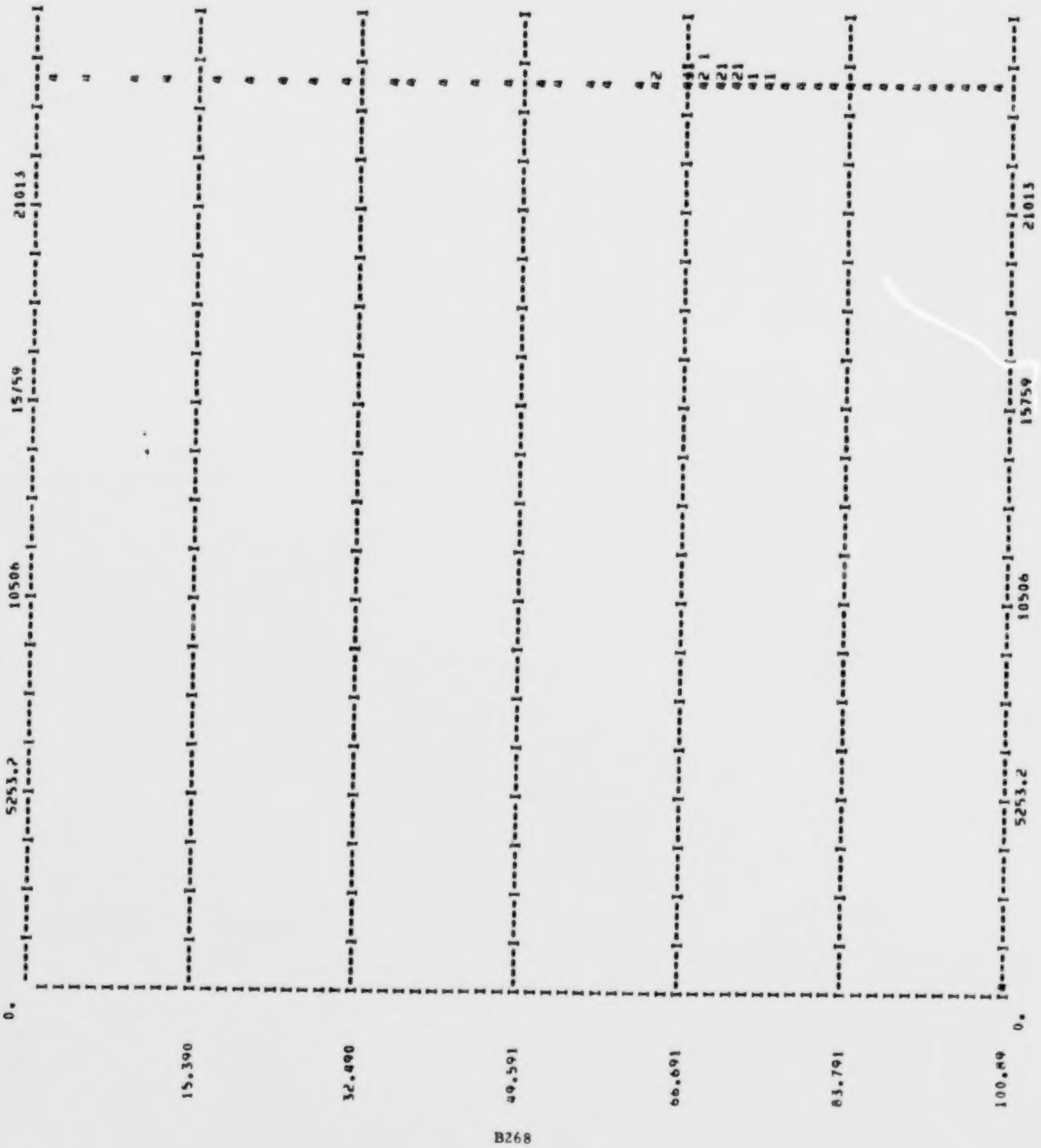
RUN W-S-2

```
                                  GRAPH OF    SIZE  VS Y AT TIMES
          4229,3132              4865,1143          5500,9153          6772,5175
             RANGE OF      Y     PLOTTED         0.                    100,89149
             RANGE OF   SIZE     PLOTTED         0.                    929,53699
```



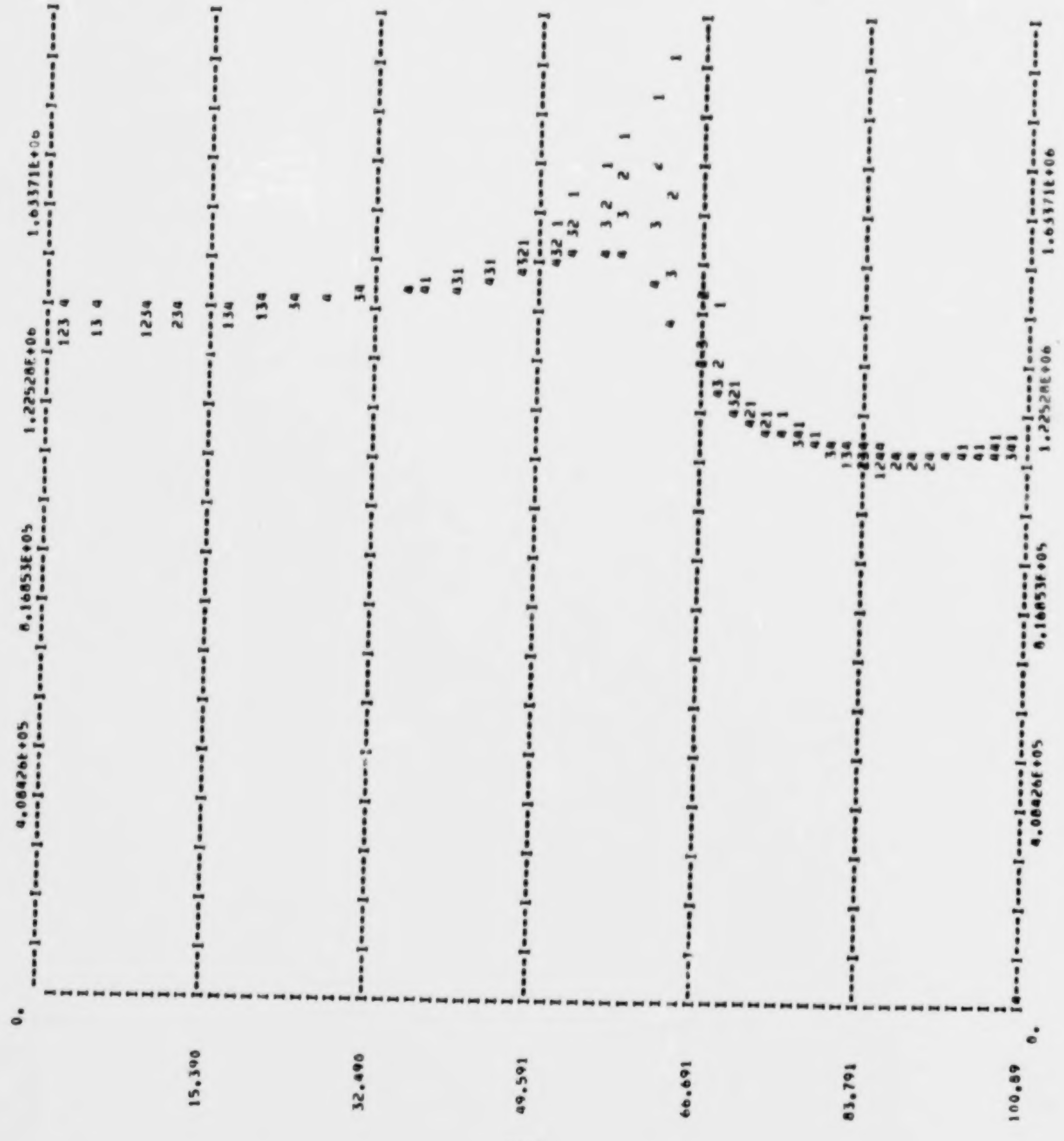
RUN W-S-2

```
                              GRAPH OF      XO    VS Y AT TIMES
      4229.3132            4865.1143              5500.9153            6772.5175

               RANGE OF     Y    PLOTTED      0.                    100.89149
               RANGE OF    XO    PLOTTED      0.                    24952.482
```



RUN W-S-2

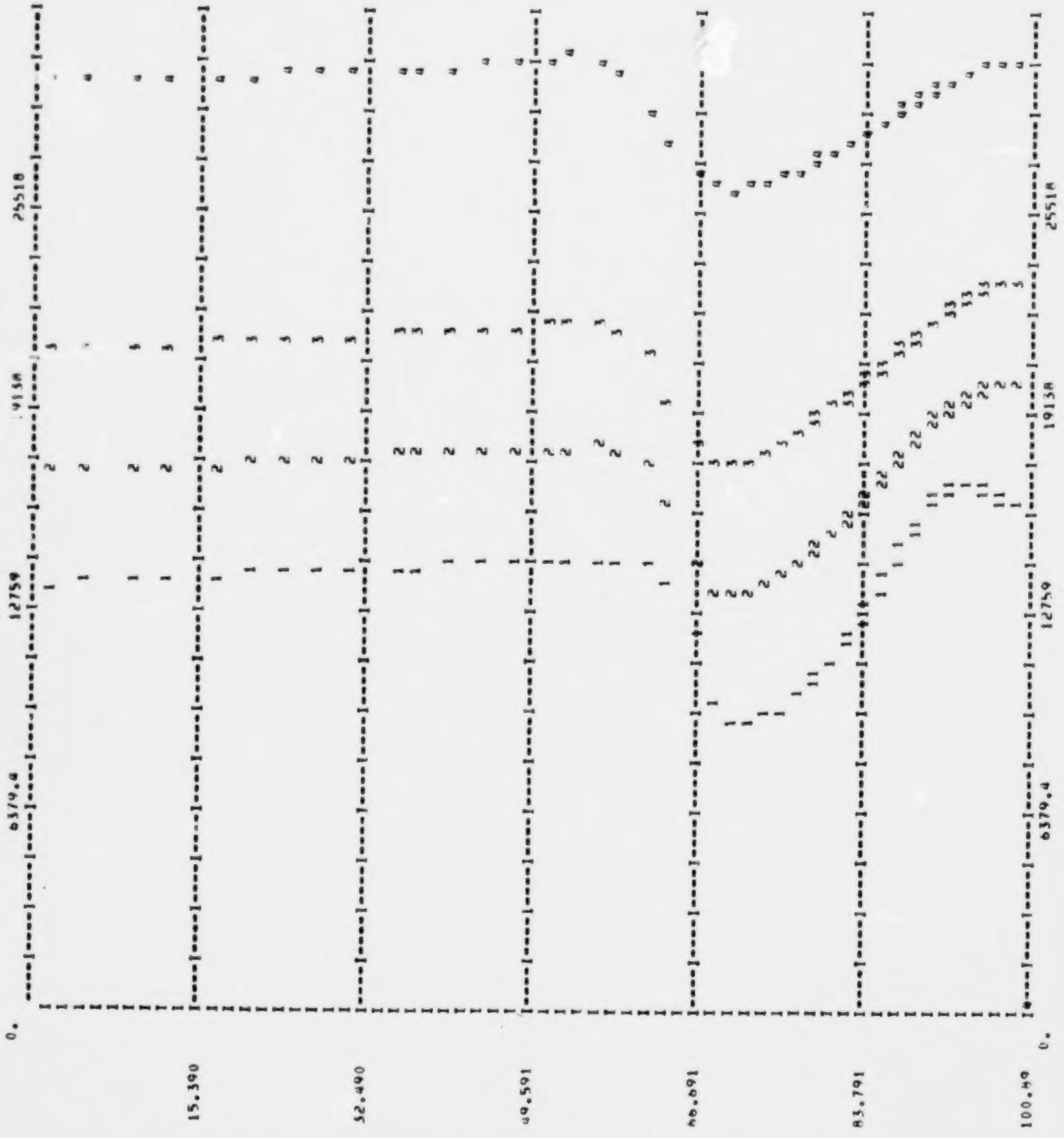
```
                         GRAPH OF SIGMA-X VS Y AT TIMES
   4229.3132          4865.1143          5500.9153           6772.5175

          RANGE OF     Y    PLOTTED         0.                   100.89149
          RANGE OF SIGMA-X  PLOTTED         0.                   1940025.6
```



RUN W-S-2

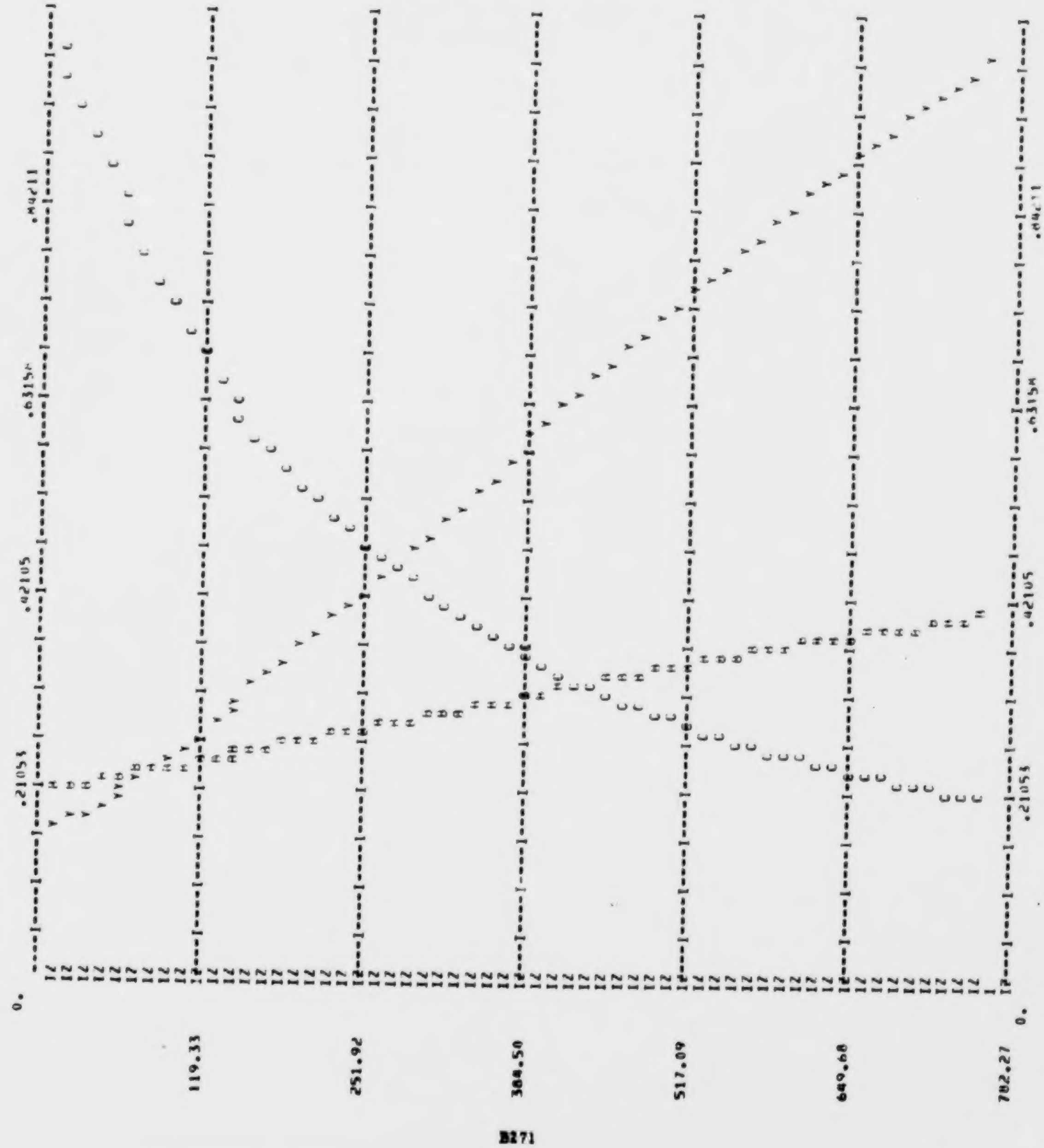
GRAPH OF SIGMA-Z VS Y AT TIMES

```
4229.3132           4865.1143           5500.9153           6772.5175

         RANGE OF      Y    PLOTTED          0.                      100.89149
         RANGE OF SIGMA-Z PLOTTED          0.                      30302.059
```

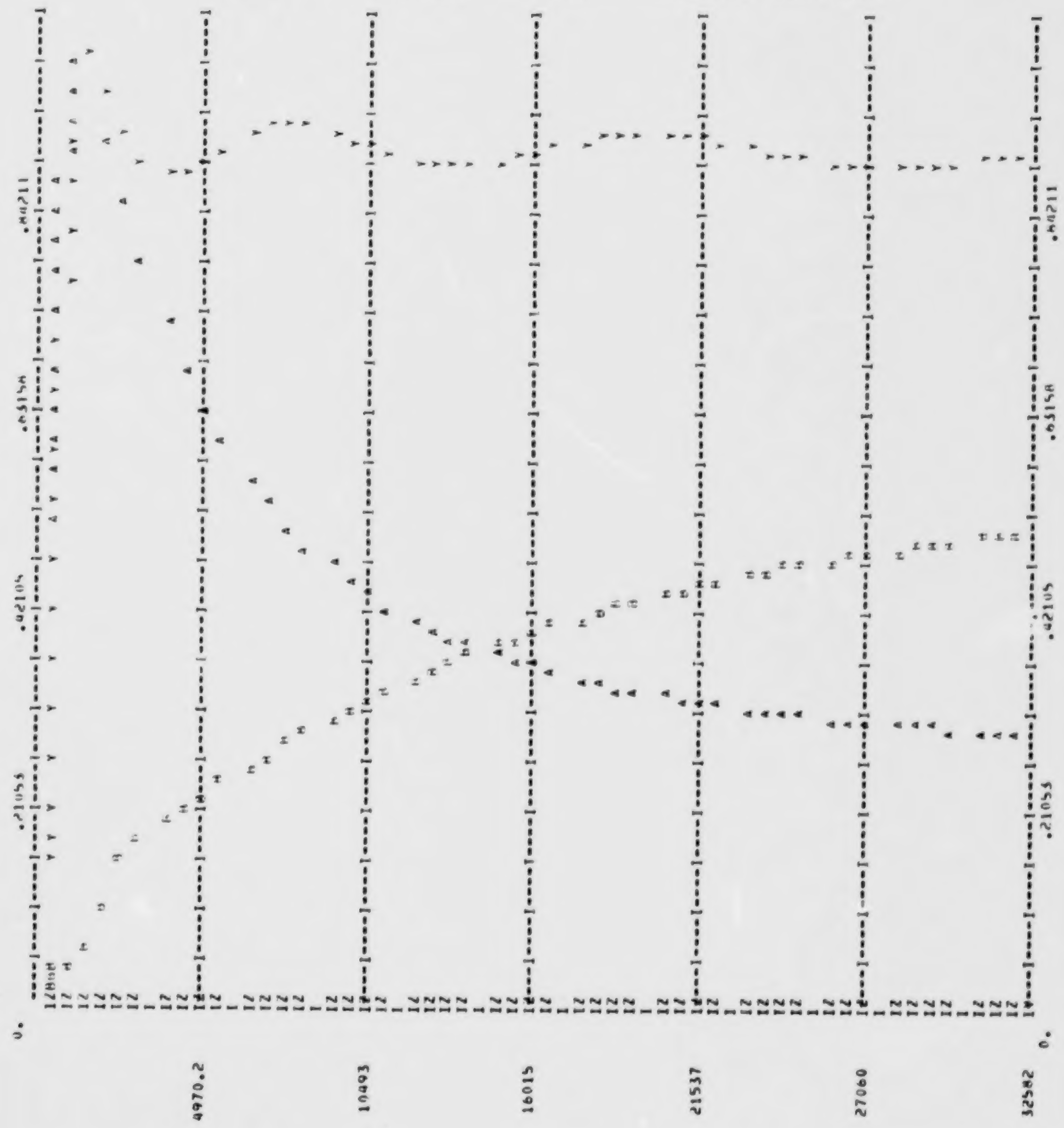


RUN W-4S-1

```
INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.           782.27

                         DEPENDENT VARIABLES

SYMBOL               Y             H              C              Z
MAX PLOTTED      54.432        41.923       1.87143E-03     0.
MIN PLOTTED      0.            0.           0.              0.
REMARKS          VERT. DIST.   RADIUS       FLUID CONC.     HOR. DIST.
```



```
                              RUN W-4S-1
     INDEPENDENT VARIABLE IS HOR.DIST. OVER RANGE      0.            32582

                          DEPENDENT VARIABLES

     SYMBOL              A              H              Z              Y
     MAX PLOTTED      21.003         540.60         0.             59.003
     MIN PLOTTED      0.             0.             0.             0.
     REMARKS          VERT. SIZE.    HOR. SIZE      HOR. DIST.     VERT. DIST.
```



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